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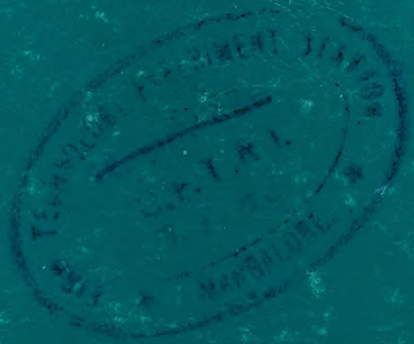
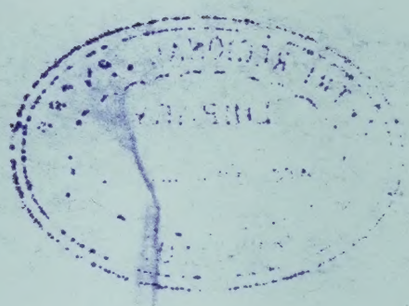
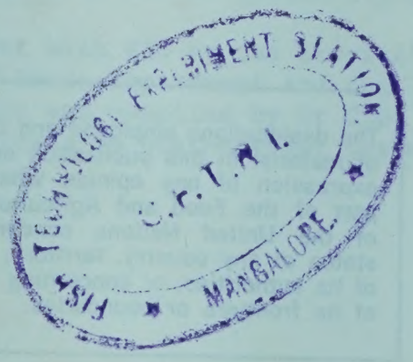


THE PREVENTION OF LOSSES IN CURED FISH

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS





THE PREVENTION OF LOSSES IN CURED FISH

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1981

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PREPARATION OF THIS DOCUMENT

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The document was prepared under contract with FAO by the Tropical Products Institute, London (UK). Personnel from the Animal and Foods Department and the Tropical Stored Products Center of TPI were involved, and the document was compiled by Dr C.D. Wood. The intent of this document is to provide information and data on post-harvest losses of cured fish, causing factors and means of their reduction.

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ABSTRACT

The paper reviews problems of the post-harvest losses in cured fish. The importance of this commodity in the tropics and existing methods of its handling, processing, storage and distribution are discussed. Information on the present level of losses due to micro-organisms, insect infestation and physical breakage is provided. The loss causing factors are reviewed in detail and means of reduction of losses given. Finally the paper provides recommendations for improvement in handling, storing and distribution, as well as ideas on the preparation of quality standards of cured fish and how to approach the assessment of losses in cured fish.

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1. INTRODUCTION

1.1 The Problem of Traditional Fish Curing

Losses of cured fish during and after processing can be high and due to a wide variety of causes. This review has been prepared to gather such information as exists relevant to the reduction of post-harvest losses of traditionally cured fish products. It will become evident from chapters 2 and 3 that post-harvest losses of cured fish can be compared more to the losses occurring in cereal storage than to the problems of frozen and chilled fish products, the more familiar areas of fish technology research in developed countries. Partly for this reason information relevant to solving this problem is scattered, often being in publications which are unfamiliar to workers in fisheries. A meeting to discuss the problems of fish processing in Africa (FAO, 1980) highlighted the problems of the fish curing industry and the lack of an informed strategy to improve the present situation.

Fish curing methods have developed over many centuries, largely to suit the prevailing climate. Traditional fish processing is therefore very weather-dependent, and adverse conditions may cause very considerable losses. The processing methods used and the organization of product storage and distribution will also affect the levels of losses. The available figures for the extent of losses are mostly averages which can be misleading, since they give only a very general idea of a very complex and variable situation. As an indication of the probable scale of the problem an estimated loss of 3 million tons (wet weight equivalent) per year dried fish has been suggested (U.S. National Academy of Sciences, 1978). This may be compared with the quoted annual production of 12 million tons (wet weight equivalent) of dried fish. Also it was concluded that "FAO estimates for fisheries in some countries place fish losses among the highest for all commodities", along with the qualification "there are very few documented studies which support this" (U.S. National Academy of Sciences, 1978). These losses occur largely in tropical areas where there is a general shortage of animal protein in the diet. There is no doubt that the prevention of these losses would have an appreciable impact in increasing the world's supply of fish for human consumption.

1.2 Scope of the Review

For the purposes of the review cured fish are defined as fish preserved without the need for refrigeration or freezing, but excluding sterilized products in air-tight containers (such as canned fish). Drying, smoking and salting, and combinations of these treatments are the basic means whereby such products are prepared. The cured fish products under consideration are intended primarily for human consumption and are consumed mainly in tropical countries. The marinated and smoked fish products of the type which require refrigeration will not be included.

Losses are defined as the nutrients from, and value of, fish which is potentially available for human consumption but fails to be consumed or sold as traditionally cured products. These losses are due to spoilage rendering the fish or fish products unfit to eat, to physical destruction, and to the lowering of the nutritional value of the product. The exact nature and causative agents of these losses are considered in chapters 3, 4 and 5. The discarding of fish offal, trimmings and other material considered unsuitable for human consumption, the discarding of edible fish such as by-catch, although representing the loss of a resource, is regarded as being outside the scope of this review. Similarly losses such as those of up to 30 percent (Amano, 1962) of the protein nitrogen during fermented fish production, and 1-5 percent (Tarr, 1962) of the protein during wet salted fish preparation are regarded as an intrinsic part of the processes involved, and therefore will not be considered in detail.

As the losses occur largely in tropical countries, the review concentrates on the existing processing, storage and distribution methods and their associated problems under tropical conditions. After describing the extent and causative agents of the losses, the work done so far on their reduction is reviewed. Finally an attempt is made to integrate the information available and approaches aimed at loss reduction are suggested.

The lack of financial and other resources of the small-scale fish processor is inevitably a limiting factor (James, 1977). There are, however, many improvements which could be implemented with few resources even if total prevention of losses proves impractical.

2. CURED FISH IN THE TROPICS

2.1 The Importance of Cured Fish

2.1.1 General availability

While the global fish catch is increasingly being preserved by freezing, this trend has been caused largely by the increasing popularity of frozen products in developed countries (James and Krone, 1977). In tropical countries fish spoils very rapidly due to the high ambient temperatures, but ice plants and freezers are frequently lacking. Traditional curing methods therefore still provide the major method of preserving fish which cannot be sold fresh. In India, for example, only about 5 percent of the marine fish landings are frozen, but 21 percent are preserved by traditional curing (Chakraborty, 1978).

Cured fish is a part of the staple diet in many tropical countries (see, for example, Sidaway and Balasingam, 1971, on Malaysia; Périssé, Stoces and Paci, 1974, on Zambia). In Japan, Southeast Asia and Africa certain cured fish delicacies are greatly relished and the Japanese still consume appreciable quantities of traditionally cured products (Tanikawa, 1971) in spite of the availability of a sophisticated frozen and fresh fish distribution system. This is because cured fish is often used in the preparation of specific food dishes such as stews and soups. Hence the use of these products has become closely integrated with the eating habits of the consumer, and unless these change substantially the consumption of cured fish is likely to remain high. Fish curing is an established industry in most tropical countries, and there is little evidence that its importance is likely to decline appreciably in the near future despite attempts to introduce ice and freezer plants to these areas (James, 1977, a; Jones and Disney, 1977).

2.1.2 Regional variations

If distribution in a fresh state is possible due to an easily reached market, curing is often of relatively minor importance. In Sri Lanka, for example, only 11 percent of the fish landed is preserved by curing (see Table 1), and in the heavily populated state of Johore, Malaysia, 9.6 percent of the fish landed is cured (Sidaway and Balasingham, 1971). In isolated regions such as Lake Chad, Africa, up to 95 percent of the catch is cured (Osuji, 1977), and in the lightly populated state of Trengganu, Malaysia, 42.4 percent of the fish is preserved in this way (Sidaway and Balasingham, 1971). Some examples of national variations in the levels of cured fish production are given in Table 1.

During peak fishing seasons or periods of glut the proportion of the catch used for curing will increase as surplus fish which cannot be sold fresh can usually only be preserved by these methods. Thus cured fish production can vary markedly both regionally and seasonally. Also some species may be particularly popular dried, or conversely highly popular in the fresh form. This can lead to marked species differences when considering what proportion of the catch is cured (see Sachithananthan, 1976).

2.1.3 Importance in nutrition

Fish is rich in protein with an amino acid composition very well suited to human dietary requirements, comparing favourably with eggs, milk and meat in the nutritional value of its protein (reviewed by Heen and Kreuzer, 1962; Borgstrom, 1962; MAFF, 1978). Lack of sufficient protein of high nutritional value is one of the most widespread nutritional deficiencies, being commonplace in many tropical countries (see Aylward and Jul, 1975; Borgstrom, 1972; Rechcigl, 1973). An increased supply of cured fish could do much to alleviate this situation as in the poorest societies fish, particularly as cured products, is often a significant source of high quality dietary protein (see Borgstrom, 1962; Teutscher, 1979), as well as being the least expensive source of animal protein available (for example, see Périssé, Stoces and Paci, 1974, on Zambia; Balachandran, Perigreen and Nair, 1978, on India; Ricketts and Rodrigues, 1971, on Kenya).

Table 1

Utilization of fish catches in some tropical countries
('000 t liveweight)

Country	Fresh	Cured	% cured of total catch	% fish as total dietary animal protein
Africa (inland)				
Chad	35	82	70.1	37
Malawi	21	21	50.0	43
Africa (coastal)				
Senegal	147	62	19.7	60
Ghana	74	151	67.1	64
Nigeria	86	104	54.7	18
Asia				
Bangladesh	717	53	6.4	52
Sri Lanka	91	11	10.6	42
Philippines	922	310	25.2	53
Indonesia	700	650	46.7	68
Iraq	36	3	7.7	6
Latin America				
Mexico	132	25	6.0	8
Brazil	352	136	20.7	9
Chile	94	2	0.2	10

Source: Teutscher, 1979

Fish contains some vitamins, minerals and is a minor calorie source, in addition to its very considerable nutritional significance as a supply of protein. An analysis of *per caput* dietary animal protein supplies in tropical regions and the contribution that fish made to these is shown in Table 2. It can be seen that in general fish is a major part of the diet in tropical areas such as Africa and the Far East. There are, of course, regional variations (see Table 1) and local exceptions to this generalization. It is noteworthy, however, that fish is a major source of animal protein in some of the world's poorest countries.

2.2 Traditional Processing Methods

2.2.1 General

The following section is intended as a brief guide to traditional processing methods, and is essential background as the types of losses described subsequently stem directly from the limitations of these methods. The principles whereby cured fish are preserved have been previously reviewed in some depth (Burgess *et al.*, 1965; Waterman, 1976), and are considered in chapter 4. In outline, the water activity (Aw), which is a measure of the amount of water in the foodstuff available to support the growth of micro-organisms, is reduced until spoilage processes are prevented or at least greatly slowed. This is done by drying the fish to remove water directly or by adding salt to it to render the moisture unavailable to micro-organisms.

Some preparation before salting, drying and/or smoking is generally performed. Splitting, gutting and scoring is essential for all but very small fish to expose a large surface area to the particular treatment. Inadequate preparation may result in spoilage if the lowered Aw which preserves the fish cannot be achieved sufficiently quickly.

Table 2

Per caput protein supplies of some tropical areas in 1974

	Animal Protein	
	g/day	% by fish
Africa	9.3	24
Far East	7.5	32
Latin America	25.3	8
Near East	14.0	6

Source: Teutscher, 1979

2.2.2 Salting

Fish can be salted in three basic ways:

a. Kench curing, where solid salt is rubbed into the fish flesh, the fish then being stacked while the salt penetrates the flesh and the extracted moisture drains away.

b. Pickling, which is similar to kench curing except that the moisture extracted from the fish is not allowed to drain. The fish becomes immersed in a very salty "pickle" of extracted fluids.

c. Brining, where fish are soaked in a prepared concentrated salt solution.

There are many different rationales used for salting and the final salt contents of the products can vary considerably. Most salted fish is subsequently dried and it is the combination of salt and moisture contents which largely determine the keeping qualities of the product (see chapter 4). Sachithananthan (1976) described over 200 types of dried fish

products consumed in Sri Lanka where species and/or method of processing show many variations. The composition of 20 varieties of salted dried fish found in Sri Lanka were also described, these being shown in Table 3. Subba Rao (1967) illustrates the diversity of traditional processes, many methods, some involving several salting stages, being described. The methods are based on local traditions, and little methodological investigation has been done to relate processing technique to the composition and storage characteristics of the final product.

Table 3

Proximate composition of twenty varieties of locally produced dried fish in Sri Lanka

Variety	Composition (% by weight)			
	Moisture	Crude protein	Crude fat	Mineral ash
Seoliodon sp.	26.9	45.8	1.6	25.7
Kowala coval	20.7	50.6	4.1	24.6
Sardinella albella	29.9	43.4	2.2	24.5
Sardinella sp.	34.4	46.7	1.1	17.8
Amblygaster sirm	28.0	46.3	4.4	21.3
Dussumieria acuta	32.5	43.7	5.4	18.4
Anchoviella indica	16.2	52.8	5.8	25.2
Chricentrus dorab	37.1	45.0	1.8	16.1
Tachysurus sp.	30.9	45.1	2.9	21.1
Exocoetus sp.	20.7	44.9	6.5	27.9
Sphyraena sp.	31.9	47.5	1.6	19.0
Lates calcarifer	30.8	48.1	1.0	20.1
Selaroides leptolepis	30.5	41.4	5.4	22.7
Caranx sp.	30.1	47.1	3.0	19.8
Chronemus lysan	32.4	44.2	2.3	21.1
Leiognathus sp.	26.1	41.4	4.0	28.5
Tilapia mossambica	24.7	41.4	3.3	30.6
Rastrelliger kanagurta	30.2	45.3	2.0	22.5
Katsuwonus pelamis	35.7	45.0	1.7	17.6
Scomberomorus commersoni	31.2	45.7	1.1	22.0

Source: Sachithananthan, 1976

2.2.3 Drying

Fish can be salted by any of the above methods prior to drying, or it can be dried unsalted. Whole small fish or split large fish are simply spread in the sun in tropical countries, allowing moisture to evaporate from the flesh surface. Fish may be laid directly on the ground, on mats or on raised racks. In colder climates fish can be hung up to dry in the wind, this process being slower than sun drying but the lower ambient temperatures slow the spoilage processes.

The principles of fish drying have been reviewed in depth by Waterman (1976). The initial drying rate depends on the speed with which water leaves the fish surface, while later drying also depends on the rate at which water diffuses from the centre of the fish to the surface. High temperatures, low atmospheric relative humidities (rh) and high air speeds aid evaporation, while thinly sliced or small fish (with large surface areas relative to their mass) will speed up the rate of diffusion by decreasing the distance from the centre to the surface of the fish. A high fat content in the flesh will act as a barrier to diffusion and slow the drying rate.

Turning the fish from time to time during drying aids the process by exposing more of the surface of the fish to the air. Too rapid an initial drying results in the surface flesh forming a hard crust (case hardening), which slows the rate of diffusion of water from the centre to the outer surface of the fish. Bacteria can multiply in the damp interior while the Aw is sufficiently high, causing the centre to spoil while the outside appears satisfactory. An initial drying period in the shade is sometimes used to prevent this from happening, although Etoh (1975) found that in Somalia poor processing techniques often led to case hardening and the flesh at the centre of the cured products often showed a resultant deterioration. This is almost certainly not an isolated example, even though, if the drying conditions are good, drying in the shade is as fast as sun drying (Cole and Greenwood-Barton, 1965; Aref and Timbely, 1964), and may give a less discoloured product (Cole, 1963).

Drying times vary considerably depending on the process and weather, but 3-10 days is generally required to prepare a typical sun-dried product (Waterman, 1976). Sidaway and Balasingham (1971) and Poulter (1980), noted that much salted-dried fish had moisture contents which were too high to ensure anything other than very short shelf lives. Cole and Greenwood-Barton (1965) reported moisture contents varying from 36 percent to as much as 65 percent in one location. These findings may reflect an economic pressure on the fish curer not to over-dry the fish so as to sell a greater weight of product (as additional water), although fish is often sold by volume rather than weight. There may also be a consumer preference for relatively moist fish compared to very dry products (FAO/UNDP, 1976).

2.2.4 Smoking

A wide variety of smoked products can be prepared and these have been reviewed in detail by FAO (1970). This review is limited to the traditional smoked products found in tropical areas and the relatively lightly cured products which require refrigeration will not be considered. Traditional smoking is generally hot-smoking which cooks and partially dries the fish as well as imparting a smoky flavour.

The fish may be salted and/or partially sun-dried before smoking and further drying may take place after smoking, depending on the final moisture content required. Traditional smokehouses are very varied in construction and are frequently fairly primitive. Simple bamboo smokehouses, with iron grills placed over fire pits or oil-drum fire boxes are found in Southeast Asia (Subba Rao, 1967). Mills (1979) described simple pit and platform kilns by Lake Chad in Africa, and Clucas (1976) found similar arrangements being widely used in Zambia.

Smoking itself can be performed for as long as three days or just for one day. The open nature of many traditional fire pits means that smoke densities and temperatures are very crudely controlled by regulating the fire itself, and the process requires a high degree of supervision by an experienced operator. Improved types of kilns are available and are being used in some areas; these are described in chapter 6.

Although the Aw of the final product will determine its long-term storage life in a way similar to that of other dried products, it must be noted that the cooking process has a pasteurizing effect and wood smoke acts as an inhibitor of microbial attack (see chapter 4). Very moist products, which must be consumed in 1-2 days, are popular and can be compared with grilled, fried or boiled fish which have very short shelf lives. Kagan (1970) reported moisture contents of over 60 percent for some unsalted hot smoked fish in Ghana. The pasteurizing effect of cooking will be the major factor in short-term preservation and it may be argued that such processing methods are a means of preparing the fish for eating as much as a method of preservation.

2.2.5 Undried products

The majority of cured fish products found in tropical areas are dried. Fish can be pickle-cured and not subsequently dried (pickled herring for example), but these products require low ambient temperatures (about 10-12°C) for the fish enzymes to "ripen" the product by limited proteolysis (Voskresensky, 1965). At temperatures above 20°C the flesh solubilizes due to excessive proteolysis (Heen, 1974). Subba Rao (1969) reported that hilsa and mackerel were pickled or kench cured and not subsequently dried in India, but the shelf life of such products would be relatively short. The fermented fish products (reviewed by Van Veen, 1965; Subba Rao, 1969; James, 1975; and most extensively by Mackie, Hardy and Hobbs, 1971), popular in Southeast Asia, are the only really quantitatively important wet cured fish products found in tropical countries. The process is comparable to pickling except that the higher ambient temperatures result in the enzymic digestion of the flesh to form a very salty paste or liquid. It can take up to a year for the process to be completed, and the loss of nutrients associated with the process is considered to be an intrinsic part of the processing technique.

2.2.6 Dried products

Most cured fish is dried to yield a hard, sometimes brittle, product. It can be in the form of whole fish, intact if very small, or split open and gutted. Alternatively the fish can be cut into chunks or strips. The product is often in irregular pieces with little resemblance to the fresh fish in appearance.

Although salting is widely practised, there are areas where it is infrequently used. In inland African fisheries salting is particularly rare (see McLellan, 1963, on Uganda; Aref and Timbely, 1964, on Mali, Proctor, 1972, on Zambia; Osuji, 1973, on Nigeria; Meynell, 1978a, on Malawi). Even in areas where salting is common it is rarely conducted to the exclusion of unsalted dried fish production. In India, for example, about 9 percent of the catch is salted and dried while 12 percent is sun-dried without salting (Kandoran, 1976). Simple sun-drying remains a particularly common method of preserving small fish such as sardines (Subba Rao, 1967; Cole, 1963). It appears that the cost and availability of salt are major factors in determining the extent of its use, although local preferences and traditions are significant. This is discussed in greater detail in chapter 6.

Similarly the use of smoking as a curing technique is determined by the availability of fuel and local traditions. It is very widely practised in Africa, some 35 percent of the total landings in tropical Africa being processed in this way (FAO, 1970), but it is a technique of relatively minor importance in Asia and Latin America.

2.2.7 Limitations of traditional processing methods

As a means of preserving fish the traditional methods have certain technical limitations. Very fatty fish may not dry satisfactorily and in wet weather fish drying may not be possible at all. Fatty fish, and all fish during wet weather, are therefore particularly susceptible to the types of losses described in chapter 3.

The simple sun drying of intact fatty pelagic fish such as sardine is common practice in areas where seasonal gluts occur, and such techniques are generally unsatisfactory for processing fish of this nature. While discussion of the disadvantages of using such fish for meal production is outside the scope of this review, it must be noted that one of the reasons why this is a popular process is that traditional curing is technically unsatisfactory and inadequate to cope with the large-scale landings which are often achieved. The drying periods required and the low moisture contents needed to ensure the keeping quality of the end product will also increase the tendency of the fat to become rancid as traditional processes do little (if anything) to inhibit fat oxidation by atmospheric oxygen.

The traditional processes of salting and smoking may be continued even under adverse conditions if the processing facilities are sufficiently weatherproof. Fish can be held for several weeks if heavily salted when rain threatens (Cole and Greenwood-Barton, 1965) and

drying by smoking can still be performed. The drying heat of the tropical sun is, however, fundamental to much traditional fish curing and its absence is inevitably disruptive. Even if the rain actually falls mainly at night, high daytime humidities and cloud will greatly slow the drying process (Meynell, 1978). Fishermen may limit their activities if they are unable to preserve and sell their catch, although it must also be noted that poor weather may disrupt sea-fishing activity anyway. The stormy weather associated with the monsoon season, for example, greatly restricts fishing off the west coast of India (FAO/UNDP, 1979). Sachithananthan (1976) notes that both wet and dried fish production was low during the monsoon season in Sri Lanka. Ismail (1980), however, suggested that new improved fishing boats may be able to operate under monsoon conditions, hence creating more overt processing difficulties. Techniques such as shore seining may still be practiced, and Nathan, Doe and Chakraborty (1980) outlined how in Andhra Pradesh, India, the monsoon greatly disrupts processing ironically during the period when shore-seine catches are at their highest.

2.3 Handling, Storage and Distribution of Dried Fish - Traditional Practices

It is impossible to describe the situation in every country as the length and conditions of storage, as well as the distances involved in product distribution, can vary considerably. Relatively large-scale trade in dried fish, which can be international in scope, is to be found in some areas. The export of dried fish to Sri Lanka from Pakistan (Disney, 1974a), and from Aden and India to Sri Lanka are notable examples (Cole, 1963; Subba Rao, 1967; Bell and Disney, 1976). Over 3 000 t of cured fish was imported by Sri Lanka in 1977 (FAO, 1978), and over 30 000 t had been imported in some previous years. Periods of 2-12 months between processing and the consumption are typical for dried fish passing through Aden (Green, 1967), while in contrast in Malawi products were usually consumed locally within a month (Meynell, 1978, a). This affects the patterns of trade in cured products rather than the techniques used, and a description of a particular situation will be used to provide an illustration of the problems.

The overland trade in dried fish from relatively remote fish landings to centres of population, such as the dried fish trade in Nigeria (described in detail by Rollings and Hayward, 1962, 1963; Osuji, 1973, 1975a, 1976), highlights many of the storage and distribution practices currently used in tropical countries. On Lake Chad fish are landed and processed at small scattered sites which lack basic amenities such as a piped water supply. Sun drying and smoking are the most common of the traditional curing methods, and salting has recently been introduced but is not widely used. After processing the dried fish is accumulated until there is sufficient to send to a collecting point, the town of Maiduguri in this particular case.

Uncovered woven baskets are often used to take fish to the collection site for repacking, where old and much used cardboard boxes are commonly used for packing the fish for distribution (Osuji, 1976). Jute sacks, palm leaf cartons and other simple materials are more common in some other areas (Blatchford, 1962; Kandoran and Valsan, 1974). Transporting dried fish to Maidguri is difficult, but the completion of an all-weather road to Baga on the lake in 1969 opened up the area to lorries. Donkeys and camels are still used to take the cured fish to the road, a process which is long and arduous from the more distant landings. Collection by boat, also a slow process, is also practised where appropriate. Maiduguri is over 200 km from Lake Chad at its nearest point, but lies on an all-weather road linking it to the large population centres of Lagos and eastern Nigeria. For this reason dried fish prepared at the many processing sites bordering Lade Chad are collected for distribution to the major markets to the south. Some 26 500 t of dried fish passed through the town in 1971 (Osuji, 1976).

Warehouses used for fish storage in this area are often open, mud or mat walled and roofless (Osuju, 1976). The fish is unpacked, sometimes redried, and repacked for storage and distribution. Fish from many processing sites are mixed together at this stage and little organized attempt is made at controlling the quality of the product, although poor quality badly infested fish will fetch lower prices (Meeren, van der, 1980). In other areas practices may include the use of roofed warehouses, and the fish may be stacked loosely on the floor

(Cole, 1963), but storage conditions are generally as primitive as those found by Lake Chad. Such facilities often allow the dried fish to become wet during rainy weather (Disney, 1968). Insect infestation is allowed to continue unchecked and insects from infested fish will rapidly attack previously uninfested fish as no attempt is made to prevent this from happening.

By contrast, distribution in Nigeria is more dependent on modern facilities such as the use of lorries and all-weather roads, donkeys being used only where the processing area cannot be reached by other means. Open topped lorries are, however, in common use and little attempt is made to protect fish from the weather (Osuji, 1976).

By the time the dried fish arrives at the market it has become well mixed with products from many processing sites. The fish may be sorted into product types such as smoked and unsmoked, salted and unsalted, and a very limited attempt at sorting by quality may be practised by the individual trader. At the market stall the fish are generally kept loose in baskets or on mats so that purchasers can select fish pieces by hand. It is common practice to sprinkle water on dried fish to prevent crumbling during handling by potential customers (Osuji, 1976).

Thus, with the exception of the more recent improvements due to the partial mechanization of distribution, commerce in dried fish is carried out using the same techniques that have been practised for many years.

2.4 Quality Preferences of Consumers

While formal quality control as such does not usually exist for cured fish products, and regional tastes vary, some tentative general observations can be made regarding consumer preferences. While poor quality fish (badly infested, broken or mouldy, for example) does seem to lose market value (Beatty, 1969; Mills, 1979), there is some evidence that especially high quality products do not necessarily have a correspondingly higher market value. Disney (1974) in Malawi, and Breslin and Hoffman (1975) in Pakistan, found no evidence that better cured products would fetch higher market prices and Watanabe and Mensah (1976) were unable to correlate retail prices and organoleptic quality for salted dried fish in Ghana. It is, however, generally easier to sell good quality products at the maximum market price than similarly priced inferior products.

3. POST-HARVEST LOSSES OF CURED FISH

3.1 Losses in Nutritional Value

3.1.1 Protein damage

Some loss of nutrient is inevitable during most processing procedures, and traditional fish processing is no exception. It does appear, however, that salting and drying effectively preserves much of the original nutritional value of fresh fish (Cutting, 1962; Munro and Morrison, 1965; Aitken *et al.*, 1967), but excessive heat treatment is known to impair the nutritional value of fish proteins as a result of a variety of chemical reactions (Tarr, 1962; Aitken and Connell, 1979). Traditionally prepared hot smoked products may be charred or burnt in extreme cases due to the uncontrolled nature of the process (Clucas, 1976). Hoffman *et al.* (1977) demonstrated that traditionally prepared hot smoked fish can suffer appreciable protein damage, finding a loss of lysine availability in traditionally smoked *Tilapia nilotica* bought in Uganda and *Sardinella aurita* from Ghana. There is no evidence that the temperatures typically reached during sun drying (up to 50°C reported by Meynell, 1978; Mills, 1979) cause any appreciable loss of nutritional value of the protein.

The exposure of wet fish to high temperatures is the most likely cause of protein damage. Drying at 75°C and smoking at 100°C lowered lysine availability and net protein utilization (NPU) (Hoffman *et al.*, 1977), however Aitken *et al.* (1967) heated dry cod to temperatures up

to 115°C without an appreciable decrease in NPU. Similarly a temperature of 120°C did not appear to cause any nutritive damage to dry fish protein concentrates (FPC) even after four hours exposure (Dubrow and Stillings, 1970). Obileye and Spinelli (1978) smoked Tilapia flesh for two hours at 30°C and dried it to a moisture content of 40 percent before hot smoking for 12 hours at 70°C to 25 percent moisture. Such treatment caused only minor losses (less than 20 percent) in lysine availability, and most of this resulted from the initial drying stage rather than subsequent hot smoking. In laboratory model systems using casein mixed with glucose, low moisture contents inhibited the reactions which made lysine unavailable (Carpenter and Booth, 1973). Thus, in dried fish the protein may be less sensitive to heat damage, but more evidence is required before definite conclusions can be drawn as to the relationship between the temperature and time of treatment, moisture content of the fish and the degree of protein damage.

For smoked fish Obileye and Spinelli (1978) found that smoke itself caused a minor decrease in lysine availability, while Hoffman *et al.* (1977) found that smoke afforded some measure of protection to the protein. Both the studies agreed, however, that the effect of smoke itself was minimal. Oxidized fish fat is known to be able to react with and damage the nutritional value of protein (reviewed by Carpenter and Booth, 1973) but Arai (1980) found that the nutritive value of anchovy protein did not appear to be impaired by oxidized lipids when fed to rats.

In conclusion, therefore, it would appear that, of the traditional curing techniques, only hot smoking may lead to any significant protein damage.

3.1.2 Lipid oxidation and toxins of cured fish

Fish body oils are very susceptible to oxidation by atmospheric oxygen leading to rancid flavours (Tsuchiya, 1961). These flavours may decrease the acceptability of the product but, as traditional products are often used as flavour-giving condiments, rancid fish is not necessarily unacceptable (Waterman, 1976), and a degree of rancidity is considered normal (Watanabe and Dzekedzeke, 1970; Watanabe and Choongo, 1971). The nutritional value of the oxidized fish fat is appreciably lower than that of the fat in the natural form. There is also some evidence that lipid peroxides, an intermediate product of oxidation, are toxic (Toyama and Kaneda, 1962). Arai and Kinumaki (1980) found no evidence that the levels of rancid fish fat found in cured products causes any toxicological problems when fed to rats, although vitamins A and E can be destroyed by lipid peroxides (Olcott, 1962) and dietary rancid fat may aggravate vitamin E deficiency (March, 1962).

Cole and Greenwood-Barton (1965) noted that most tropical species are fatty or semi-fatty (fat contents over 0.5 percent) and when dried the fish fat has little protection from oxidation. Koizumi *et al.* (1980), using laboratory model systems of freeze-dried flesh from various fish species, have shown that the drier the fish the greater is the tendency for the lipids to be oxidized. Woolfe (1975) also found that in dried fish lower moisture levels were related to faster lipid oxidation rates. Salt and haemo-proteins appear to have a pro-oxidant effect (Koizumi *et al.*, 1980). The phenolic substances found in wood smoke used for fish smoking have some antioxidant activity and may provide some protection for the fat (Simpson, 1965), although Woolfe (1975) found no evidence that smoking decreased the rate of oxidation of *Sardinella aurita* lipids.

The composition of wood smoke has been reviewed by Cutting (1965). It contains a wide variety of chemical compounds, and some of these are toxic or carcinogenic. As Banwart (1979) stated "several of the chemicals found in smoke or on smoked foods normally would not be allowed as food additives". There is, however, no evidence that the levels of these chemicals ingested when eating smoked fish constitute a toxicological risk, although no work appears to have been done on the situation in tropical countries.

In conclusion it must be stated that very little is known about the levels of rancid fat and toxic substances in commercially prepared products, or on what impact such levels might have on the nutritional value of the fish, although at present it would appear to be a relatively minor problem.

3.2 Losses in Quantity and/or Quality of Product

3.2.1 Losses of uncured or partially cured fish

Before processing, or during wet weather when drying becomes slow or impossible, wet fish will spoil and become unfit to eat unless it is preserved. Deterioration starts immediately after death, and losses can occur until the Aw is reduced sufficiently to prevent the normal spoilage processes (see chapter 4). Enzymes, particularly those in the gut, will start to digest fish tissues, and gutting unpreserved fish will slow the process. Certain moulds and bacteria (see chapter 6) can grow on moist products giving the fish an unattractive appearance and odour. Minor growths are often scraped off and the fish redried, but severe attacks will soften the flesh causing it to break up and losses can eventually be total (Waterman, 1976; Van Klaveren and Legendre, 1965).

Moist fish is susceptible to damage by blow-flies, and their larvae in particular (see chapter 5). Blow-fly larvae will consume the fish flesh, and only when the fish has been sufficiently dried will it become unattractive to the adult fly for egg laying. Drying fish is often particularly exposed to birds, rodents and domestic animals. Unprotected fish may be a welcome source of food for any such creature which can gain access.

3.2.2 Losses of cured fish

End products may not be sufficiently dry to prevent the types of losses described for partially cured fish. For example, inadequately dried fish was found to be heavily infested with fly larvae by Soans and Adolph (1971). Also, under the very humid conditions which are commonly found in some tropical countries, fish particularly if salted, will reabsorb moisture and again be susceptible to these types of losses. Suryanarayana Rao *et al.* (1962) found that a relative humidity of over 70 percent was conducive to mould attack and in Malaysia, for example, relative humidities of about 90 percent are common (Sidaway and Balasingam, 1971).

Sachithananthan (1976) noted that in Sri Lanka, where there are both dry and humid climatic regions, it was the areas where relative humidities were greater than 65 percent that losses were apparently the highest. Hence the causes of post-processing losses can be identical to some of those occurring during processing.

Products which are sufficiently well preserved to prevent microbial attack are still susceptible to insect attack, and may also be eaten by scavenging animals. Beetles, especially *Dermestes* spp., are a particular problem, being able to feed on dried fish, completely consuming the flesh if unchecked. Mites are also occasionally found in cured fish (Sachithananthan, 1976). Details of the various species of insect which can infest dried fish are given in chapter 5.

Losses can also result from the physical disintegration of the fish. The sometimes brittle nature of the products, especially hot smoked ones, their irregular shape and size in conjunction with the widespread use of packaging materials which afford little protection means that the fish can be physically broken up during handling and distribution. The tendency for insect larvae to burrow into the fish increases the ease with which the products fragment and the action of moulds or the curing of spoiled fish will also lead to softened products.

3.3 Present Levels of Losses

3.3.1 General

It can be seen that the causes of losses are extremely diverse in character making their assessment somewhat complicated. Another major problem in carrying out loss assessments is that much of the fish curing trade is carried out in remote areas. Overall estimates of quantitative losses under commercial conditions have often been arrived at by purely visual assessments. Losses in weight have been measured in some surveys, but these can be misleading due

to variable moisture contents (for a fuller discussion on recommended methods of loss assessment see Appendix 2). The increased levels of supervision required for detailed loss assessment would almost certainly reduce the losses. Losses caused by birds, rodents and domestic animals, for example, would be impossible to quantify if the measurement process resulted in untypically high degrees of supervision. Meynell (1978, a) arrived at a figure of 13.6 percent for losses of this nature during the sun drying in Malawi, but clearly this will mainly reflect the degree of protection given to the drying fish in this particular region. In spite of these limitations and difficulties, however, some progress has been made and is detailed below.

3.3.2 Losses due to micro-organisms

It is quite common to use fish that could not be sold fresh as the raw material for cured products (Cole, 1963; Disney, 1968; Mills, 1979; Poulter, 1980) and to quote Cole and Greenwood-Barton (1965) "salting and drying are sometimes practised as a last resort on fish which is already almost putrid". In Mali (Guillon, 1976) and Southeast Asia (Subba Rao, 1967) it can be a common practice to deliberately allow the fish to spoil before processing starts to give the required flavour to the product. Losses due directly to microbial spoilage prior to and during processing are probably small when the weather conditions allow drying to take place, although there is no reliable data available to support this view.

The same is not the case during wet weather when fish may become unacceptably spoiled before significant drying can be achieved. Nathan, Doe and Chakraborty (1980) suggested losses due to spoilage during beach seining catch processing in Andhra Pradesh, India, may be in the order of 12-15 percent. This estimate was reached from the considerations that for about 12 to 15 days monsoon rains are usually such that drying is impossible, while beach seining is conducted for about 100 days, including the period when rain falls. During the first three years of the operation of the World Food Programme about 26 percent (presumably by weight) of the dried salted fish was lost due to spoilage (Murray and Jobber, 1968). These are very specific cases which underline that general figures are of somewhat dubious value when they are very weather-dependent.

Thus, it can be suggested that production loss due to the inability of traditional processes to dry fish under adverse weather conditions are appreciable, even though losses directly attributable to spoilage before and during processing may be small, as under the circumstances, fishing may be greatly inhibited (see chapter 2). Cured fish is often subject to attack by moulds and bacteria (see chapter 4), and it would be expected that losses would be highest under wet or humid conditions but reliable quantitative data on actual losses is not available.

3.3.3 Losses due to blow-fly infestation

The amount of damage caused by blow-fly larvae depends largely on the speed of drying and on whether the fish is salted. Osuji (1975, 1976) noted that infestation was transitory during fish drying in the Lake Chad region of Nigeria, and the (unsalted) fish dried sufficiently quickly to become protected before appreciable losses occurred. Only during the first two to three days of drying was blow-fly activity observed by McLellan (1963) in Uganda. Cole (1963) and Green (1967) also found that blow-flies were not a major problem in Aden due to the prevailing good drying conditions. McLellan (1963) noted that in Uganda blow-flies attacked unsalted drying fish only, salted fish apparently not suffering appreciably. Green (1967) and Mills (1979) also noted that blow-flies were not attracted to salted fish, although Sidaway and Balasingam (1971) suggested that blow-fly larvae do infest salted (kench cured) fish initially, prior to salt penetration.

Where salt is not used and drying conditions are poor, losses due to blow-fly larvae infestation can be heavy. Ahmed *et al.* (1978) put losses of unsalted fish due to blow-flies in the very humid conditions of Bangladesh at 30 percent, this estimate being based on the observations of local fishermen. Doe *et al.* (1977), also working in Bangladesh estimated

losses due to blow-flies at about 25 percent, so there is some agreement on the level of losses in this region. Meynell (1978a) reported losses of up to 30 percent due to blow-fly larvae while sun drying small (unsalted) freshwater fish from Lake Malawi during the wet season. In this study the wastage percent was calculated at the loss in weight of dried fish compared to the theoretical maximum dried weight, and is based on actual weight measurement rather than on a purely visual estimation. Over the period of the wet season average losses of 12.7 percent and 7.5 percent were measured at two fish processing sites, and correlations between high wastage, short periods of sunshine and high rainfall were found. For example, monthly losses of 26.6 percent and 10.3 percent at two sites corresponded to rainfalls of 85 cm and 51 cm,respectively.

Hence it may be concluded that losses of thoroughly salted fish due to blow-fly larvae infestation are small but losses of unsalted fish, although minor during good drying conditions, are very substantial during wet weather and in areas of high humidity. Poor salting techniques will, of course, expose salted fish to blow-fly attack. Under adverse conditions losses in the order of 10-30 percent for unsalted fish might be expected, depending on the degree of adversity.

3.3.4 Losses due to beetle infestation

Types of pest: *Dermestes* spp. appear to be the major insect infesting dried fish, although other minor pests such as *Necrobia rufipes* and mites have also been identified (see Chapter 5). The work of Cole (1963) and Green (1967) in Aden, Aref, Timbely and Daget (1965) in Mali, Proctor (1972) in Zambia, and Osuji (1973) in Nigeria leaves little doubt that under present commercial conditions losses of dried fish during the final stages of drying, but especially during storage and distribution caused by *Dermestes* spp. infestation, can be high.

Unsalted dried fish: Aref, Timbely and Daget (1965), studying the destruction of unsalted dried fish during distribution and storage in Mali, estimated that about 50 percent of the weight of fish was lost due to *Dermestes* spp. This figure was reached by close visual studies of the main fish landings and processing areas for a three-month period which coincided with the time when most fish were landed, coupled to actual measurements of the weight losses of fish samples kept in a commercial dried fish store for six months. FAO/PNUD (1970) recorded losses of 14-25 percent (in weight) during two months storage also in Mali. For the Nigerian cured fish trade around Lake Chad, Rollings and Hayward (1963) put product losses at 50 percent due principally to *Dermestes* spp. infestation, although the basis on which this estimate was obtained is unclear. In Senegal losses of cured fish (predominantly unsalted) have been put variously at 10 and 30 percent (Diouf, 1980) during processing and distribution, due mainly to insect damage. In Upper Volta 25 percent losses due to *Dermestes* spp. have been quoted as typical (Guggenheim, 1980). It can be seen that all the quoted quantitative reports on this type of loss come from African countries, and refer to unsalted and often hot-smoked products.

Moes (1980) has reported that a change from charring to more conventional smoking in the Lake Chad area appears to have considerably decreased the losses due to *Dermestes* spp. from the 50 percent level suggested by Rollings and Hayward (1963). Levels of losses do, therefore, depend on the processing methods used and presumably on the resultant moisture contents. Osuji (1973) noted that smoked fish with a moisture content of below 10 percent generally showed little or no infestation but moisture contents between 13 and 16 percent were very conducive to insect infestation. While this may represent a preference rather than a major protecting effect, actual levels of losses may be very dependent on the moisture content of the particular products (see also chapter 5).

The level of losses due to *Dermestes* spp. is directly related to the length of storage of the fish. The major reason why Meynell (1978) concluded that *Dermestes* spp. infestation was a minor problem in Malawi was that most dried fish was consumed within two or three weeks of processing. Storage periods of up to six months have been reported elsewhere (Aref, Timbely and Daget, 1965, in Mali; Guggenheim, 1980, in Upper Volta) and consequently the insects have more time to breed and consume the fish, thus leading to ever-increasing infestation and losses. Mills (1979) suggested that disinfested dried fish became reinfested within five days if unprotected, so actual losses are probably negligible for only a short storage period of a few days.

The loss of 50 percent by weight due to *Dermestes* spp. attack of unsalted dried (or smoked dried) fish stored for several months under current commercial conditions in a region with a dry hot climate may be a reasonable estimate, but losses would be appreciably lower than this where storage times are shorter, which is often the case.

Salted dried fish: Losses of salted dried fish due to insect damage may be appreciably lower than those of unsalted dried fish. Cole (1963) noted that in the low humidities of Aden *Dermestes* spp. larvae were unable to develop in salted fish while freely developing in unsalted dried sardines. Green (1967) confirmed that *D. frischii*, a major pest in Aden, did not infest heavily salted/dried fish under the prevailing conditions in spite of being exposed to cross infestation from heavily infested unsalted dried sardines. Osuji (1975a) found that salt similarly prevented *D. maculatus* infestation. Mills (1979) found that even light brining to give salt contents of 2-3 percent greatly reduced the numbers of *Dermestes* spp. and *Necrobia rufipes* in dried fish, although Meeren, van der (1979) was unable to demonstrate this effect when repeating the experiment. *Dermestes* spp. can attack salted fish (Aref, Timbely and Daget, 1965; Proctor, 1972; Poulter, 1980, a) and Aref, Timbely and Daget (1965) found weight losses of 23 percent in the kench-cured *Hyperopisus* spp. over five months and 9.1 percent in heavily brined *Alestes dentex* over six months, although varying moisture contents may have given rise to errors (see Appendix 2).

The precise relationship between levels of losses and salt content remains unclear but salt has a marked protective effect (see also chapter 5), although the insects may prefer unsalted fish, hence explaining the observations of Cole (1963) and Green (1967) that when unsalted and salted fish are stored adjacently the unsalted fish become infested and the salted fish remained insect-free.

Smoked fish: There is little evidence that smoking itself affords any protection from *Dermestes* spp. infestation. Aref, Timbely and Daget (1965) did find that *Dermestes* spp. larvae of the species mix found in Mali (mainly *D. maculatus*, but including *D. frischii* and *D. ater*) died on heavily smoked unsalted fish, but Proctor (1972) found that commercially prepared smoked fish were heavily infested with *D. maculatus* in Zambia and Poulter (1980, a) found unsalted smoked fish highly susceptible to infestation by the same insect species.

3.3.5 Losses due to fragmentation

Damage to the texture due to spoilage before processing, subsequent mould and bacterial growth and insect infestation will all increase the tendency for dried products to fragment. It is only hot-smoked fish, however, which appear to suffer serious losses due to fragmentation when not subject to other forms of attack. This is presumably due to the excessive temperatures used damaging the texture of the fish and may well be related to the reactions which damage the nutritional value of the protein described previously.

Under commercial conditions during the distribution of hot-smoked, unsalted fish from Lake Chad to southern Nigeria, Mills (1979) measured weight losses of 25 and 56 percent (depending on the fish species) due to fragmentation. Moes (1980) estimated that losses of 35 percent due to fragmentation might be a typical figure for this trade, and this appeared to be the major cause of losses. Beetle infestation was probably an additional factor in increasing fragmentation in this case. While some of the resultant powder is used for human consumption, some is used as animal feed, and, of course, if the packaging is open much may be lost. The usually higher price obtained for intact pieces of cured fish (Moes, 1980) means that there is a loss in value.

3.4 Susceptibility of Fish Types to Losses

As indicated in chapter 2 fatty fish may be more susceptible to losses when processed in traditional ways due to difficulties in drying, although data to support this suggestion is extremely limited. Osuji (1974) found some evidence that different fish genera may vary in their susceptibility to attack by beetles. *D. maculatus* and *N. rufipes* infested the fish species *Clarias* spp. more heavily than *Citharinus* spp., with *Heterotis* spp., and *Synodontis*

spp. being infested to an intermediate extent. Proctor (1972) also found *Clarias* spp. and *Tilapia* spp. to be relatively susceptible to *Dermestes* spp. infestation while *Synodontis* spp. and *Hydrocyon* spp. were less so. Although Osuji (1974) found some indication that at least in some cases high lipid content may increase susceptibility to insect infestation, the evidence is not conclusive. Any correlation may be indirect, with moisture content or processing method being primary factors. Other, as yet unknown, factors may be important as larval development does appear to be sensitive to the food source available (see chapter 5).

Mills (1979) found marked differences in susceptibility to fragmentation between different fish species, *Tilapia* spp. being more fragile than *Heterotis* spp. and tonkosa. Watanabe and Cabrita (1971) suggested large oily fish were particularly susceptible to fragmentation if hot-smoked. Differences in composition, texture and size may clearly affect the levels of losses due to the variety of factors previously described, but it must also be remembered that different species are often processed in different ways.

3.5 Summary of Losses and their Causes

A summary of loss causes is given in Table 4 based on the data described in this chapter, together with a consideration of the nature of the loss causing agents. It is speculative and is intended as a guide as to what problems might be anticipated under a given set of climatic conditions. Processing, storage and distribution techniques will greatly affect the type and scale of losses, so this analysis may not accurately represent the position when specific cases are examined.

3.6 Need for Data on the Levels of Losses

The assumed 25 percent level for losses quoted by the U.S. National Academy of Sciences (1978) was intended for use in arriving at a rough estimate of the worldwide loss of cured fish. From the data gathered for this review the figure seems a realistic estimate but it does not of course refer to any specific situations. It must be emphasized that loss assessment is required to discover where and how losses occur and to measure their extent, so that priority areas for loss reduction can be determined. Unless data refer to specific circumstances they are of little value when an appropriate loss reducing technique has to be selected and its effectiveness assessed.

4. LOSS CAUSING MICRO-ORGANISMS

4.1 Spoilage Prior to Processing

Fish flesh contains the nutrients necessary to support the growth of a wide range of micro-organisms. Although the flesh of newly caught fish is sterile, the skin, gills and intestines tend to carry considerable bacterial loads depending on the environment of the fish at the time of capture. At death these micro-organisms start to invade the tissues. Unpreserved fish is prone to spoilage due to the effect of these bacteria and also to the residual activity of fish enzymes. In warmer waters genera of mesophilic bacteria such as *Micrococcus, Cornyneforms* and *Bacillus* predominate (Shewan, 1961, 1966, 1977), however psychrophilic genera are also present and predominate in colder waters. These bacteria act to give the off-flavours and odours associated with spoiled wet fish and, if kept at ambient tropical temperatures without salting or drying, fish is considered to be spoiled within 12 hours.

Washing the fish surface to remove slime thus reducing the bacterial load, keeping the fish at low temperature (using ice if possible, but moistened and in the shade when not available) and careful hygienic handling to avoid bruising the flesh or further contamination are simple measures which slow the spoilage of fresh fish. As for all fish preservation techniques, the quality of the starting material can be retained but not improved by processing. Processing should, therefore, be started as soon as possible after catching to minimize the deterioration of the raw material to prepare the most hygienic product.

Table 4

Principal loss-causing agents under tropical conditions

Loss causing agent	Degree of losses under different climatic conditions		
	Dry (but possibly with overnight dew)	Humid	Rainy
(a) Spoilage prior to processing	low	low to moderate	high
(b) Blow-fly infestation	low	moderate to high	high
(c) Halophilic bacteria and moulds	low to moderate	moderate to high	high
(d) Beetle infestation	moderate to high	moderate	low (relatively)
Fragmentation is probably a major cause of loss for hot-smoked dried fish, but otherwise probably associated with insect and microbial attack. Birds, rodents, etc., may cause appreciable losses under all climatic conditions. Salted fish is less susceptible to insect attack but more susceptible to halophilic bacteria than unsalted			

4.2 Water Activity

The water activity (Aw) of a food greatly affects its susceptibility to microbial attack and it is principally by reducing this that traditional processing techniques preserve fish. The Aw is a measure of the water available in the system for biochemical and chemical reactions. For ideal solutions the Aw is defined as:

$$Aw = \frac{n_1}{n_1 + n_2} = \frac{P}{Po}$$

Where n_1 = moles of solvent

n_2 = moles solute

P = vapour pressure of solution

Po = vapour pressure of solvent (water)

For cured fish the relationship becomes more complex due to interactions between water and the fish flesh but it can be seen that drying the fish lowers n_1 (and lowers P) by removing solvent molecules, and hence will reduce the Aw. The addition of salt will increase n_2 (and lower P) and so will also lower the Aw. It is the net effect of both of these factors, therefore, which is responsible for the preservation of the fish.

The Aw is related to the equilibrium relative humidity (erh) in the following way:

$$Aw = \frac{erh}{100}$$

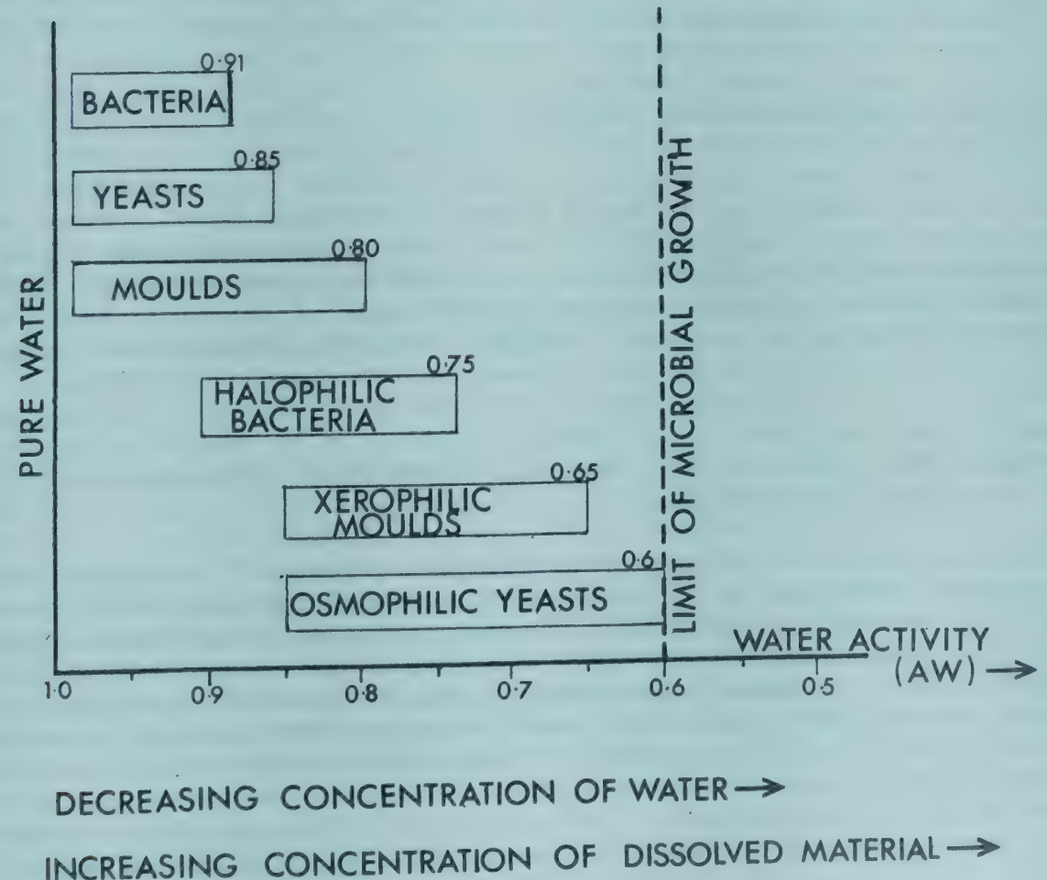
If the rh of the surrounding air rises above the erh of the fish, the surface will tend to absorb moisture, and conversely a lower surrounding rh will lead to a loss of moisture from the fish.

The Aw of a saturated salt solution is 0.75, which is insufficiently low in itself to inhibit the growth of all micro-organisms completely, hence even for heavily salted products a degree of drying is required to extend the shelf-life under tropical conditions. It must also be noted that salt levels in excess of that required to saturate the moisture in the product do not aid preservation as salt merely crystalises out of solution, and in fact makes the product more susceptible to moisture absorption under humid conditions.

Micro-organisms have an absolute requirement for water in order to grow, although the levels needed vary depending on the organism. As the Aw is lowered from optimal levels microbial metabolism becomes increasingly inhibited until growth is completely stopped (see Banwart, 1979). At Aw 0.6, or below, all microbial growth is inhibited but an Aw above this may retard growth so that micro-organisms cannot damage the product before it is consumed. Some osmotolerant bacteria can cause spoilage below an Aw level of 0.95, but those responsible for spoilage of fresh fish require a higher Aw of about 0.98 for rapid growth. At Aw levels below 0.85 development of bacteria and yeasts is normally arrested and halophilic bacteria, xerophilic moulds and osmophilic yeasts predominate (see Table 5). It is these micro-organisms which may attack cured products.

Table 5

Growth ranges of micro-organisms with respect to water activity



Source: Parry and Pawsey, 1973

4.3 Micro-organisms which May Attack Cured Fish

4.3.1 Moulds

Moulds are more resistant to the effect of dry conditions than bacteria and some are capable of survival in products with an Aw as low as 0.60, although 0.70 is the minimum Aw which will sustain the growth of most storage moulds. Spores are to be found in the air and soil and will inevitably contaminate fish during processing. Insects and mites also facilitate contamination by carrying spores on their bodies. The more common storage moulds and the minimum Aw required for their growth are given in Table 6.

Table 6

Minimum Aw for the growth of common storage moulds at their optimum temperature for growth (26-30°C)

Mould	Minimum Aw for Growth
Aspergillus halophilicus	0.68
A. restrictus	0.70
Wallemia sebi	0.70
A. glaucus group	0.73
A. candidus, A. ochraceus	0.80
A. flavus	0.85
Pencillium spp.	0.8-0.9

Source: Christensen and Kaufmann, 1974

In cured fish the most common type of mould growth is known as "dun". Frank and Hess (1941) reported an optimum Aw of about 0.75 for "dun", and a requirement for 10-15 percent sodium chloride although high glucose levels will also support growth (Vaisey, 1954). It can be seen as brown, black or fawn-coloured spots on the surfaces of the fish, and is caused by the growth of the halophillic or halotolerant fungi of the genera *Wallemia* or *Oospora (Geotrichum)*, most notably *Wallemia sebi* which appears as chocolate-coloured spots (Malevich, 1936; Frank and Hess, 1941, a). Shewan, 1961; Phillips and Wallbridge, 1977). *Aspergillus* spp. are also commonly found in cured fish (Townsend *et al.*, 1971; Phillips and Wallbridge, 1977; Wu and Salunkhe, 1978) especially those of the *Aspergillus glaucus* group including *A. amstelodami, A. chevalieri* and *A. ruber*.

"Dun" does not, however, cause objectionable flavour or textural changes in the fish by itself. Moulds can cause losses due to discoloration or visible growths which can make the product unacceptable to consumers or at least reduce its economic value (Sen and Lahiry, 1964), and they may also produce mycotoxins which can have a variety of harmful effects. The metabolism of micro-organisms in general involves the release of water, causing a localized rise in Aw around the affected parts allowing some of the less xerotolerant organisms previously inhibited to grow. Cured fish spoiled by micro-organisms is typically attacked by moulds initially, often on the tail (Poulter, 1980a). The mould growth spreads over the fish and causes an increase in surface moisture. This enables other micro-organisms such as halophilic bacteria to attack and putrify the fish. Cured fish deteriorates rapidly after the initial mould attack, so much so that Poulter (1980a) took the onset of mould attack as the end of "good quality" storage life.

All mould growth is temperature-sensitive (Table 7). It can be seen that 30°C, a common ambient temperature in tropical regions, is optimal for several species. While cold storage would clearly inhibit much mould growth, it must be noted that elevated temperatures would also be inhibitory.

Table 7

Optimum temperature for growth of some storage moulds

Species	Minimum °C	Optimum °C	Maximum °C
Aspergillus restrictus	5-10	30-35	40-45
Aspergillus glaucus group	0-5	30-35	40-45
Aspergillus candidus	10-15	45-50	50-55
Aspergillus flavus	10-15	30-35	45-50
Penicillium spp.	-5-0	20-25	35-40

Source: Christensen and Kaufmann, 1974

4.3.2 Bacteria

While bacteria do not generally grow in products with an Aw of less than 0.88 certain haloduric and halophilic bacteria will grow in cured fish with an Aw down to 0.75. Halophilic bacteria usually have a specific requirement for 10 percent or more salt in the food medium, and hence are termed obligate halophiles. Species of the genus *Halobacterium* and *Halococcus* attack cured fish, and produce a pink discoloration. They have a strong proteolytic action causing the flesh to soften and break up, and also cause off-flavours and odours. They are aerobic and cannot multiply at temperatures below about 10°C. These bacteria are very often in large numbers in solar salt commonly used for fish processing, and hence are a particular problem with salted fish. The aerobic nature of these bacteria means that their growth is stopped by soaking the fish in saturated brine provided the flesh is kept fully immersed, but adequate drying is necessary to prevent subsequent attack during storage.

Heavily salted smoked fish do appear to be generally resistant to bacterial attack, but can be attacked by moulds. Some of the chemicals found in the smoke exert an inhibitory effect on bacterial growth (Shewan, 1949) and these may account for this observation.

4.3.3 Yeasts

Most yeasts can grow at an Aw down to 0.85, but certain halophilic species will grow in high salt environments (10-20 percent NaCl). If the moisture levels are relatively high, conditions which may be found in heavily salted but poorly dried fish, it is possible that conditions may favour the growth of halophilic yeasts. The principal halophilic yeasts which can grow in a medium containing 10-20 percent salt are *Saccharomyces rouxii*, *Debaryomyces hansenii*, *Pichia ohmeri* and *Hansenula anomala* (Davenport, 1975). *Debaryomyces hansenii* is a common yeast in ocean waters, and may well survive in solar salt and in this way contaminate fish when salted. It is apparently common on sea fish (Norkrans, 1966) and can grow on a 24 percent (w/v) salt medium. Yeasts have not, however, been reported as causing appreciable losses of traditional cured fish products, and it is far from clear whether the possible growth of *Debaryomyces hansenii* on cured fish does constitute a significant problem.

4.4 Mycotoxins

Some moulds capable of growing on cured fish may also produce mycotoxins. Certain toxogenic strains of *A. ochraceus*, whose minimal Aw for growth is about 0.76, can sometimes produce the toxins penicillic acid and Ochratoxin A in dried foodstuffs with minimal Aw values of 0.80 and 0.85, respectively (Bacon *et al.*, 1973). The toxin of the greatest concern is aflatoxin produced by *A. flavus* and the closely related *A. parasiticus*. Dangerously high levels of the toxin (600-700 ppm) have been found in dried fish (Okonkwo, Umerah and Nwokolo, 1977) and *A. flavus* has been commonly isolated from cured fish in Viet Nam (Townsend *et al.*, 1971), although again there are no reported cases of it causing toxicological problems. Wu and Salunkhe (1978) isolated 114 fungi from dried shrimp of which 27 were *Aspergillus* spp. with a potential for mycotoxin production. Two of the three *A. flavus* strains isolated produced aflatoxin B_1 and G_1 on the surface of dried shrimps.

Hence, although the practice of scraping off mould colonies and re-drying fish as they become noticeably mouldy may not apparently lead to losses, problems due to mycotoxins could exist if toxic strains were present. Although there is no evidence that consumers have been poisoned by mycotoxins in cured fish, lack of research may mean that it is a problem which has not yet been positively identified.

4.5 Chemical Control of Micro-organisms in Cured Fish

The preservatives which at present appear to be of possible use in cured fish products are acetic, benzoic, propionic and sorbic acids. Acetic acid is commonly used in a wide range of vegetable pickles, and has the advantages of being cheap, widely available and non-toxic. Benzoic acid inhibits yeasts and moulds, and is used in acidic products such as jams and fruit juices. Propionic acid is particularly effective against moulds, while sorbic acid is more generally effective and is used at levels of 0.02-1.6 percent in various foods (reviewed by Banwart, 1979). Preservatives are used to extend the storage life of properly processed products, and should not be used as a substitute for adequate processing, an important consideration if they are to be successfully introduced to the traditional cured fish trade.

As regards experimental trials on cured fish there is relatively little information. Tarr (1961) reviewed the earlier work done on salted-dried fish and concluded that the use of chemical preservatives had been generally unsuccessful. Sodium benzoate had shown some promise in countering halophilic bacteria, while dipping in a 1.0 percent sorbic acid solution inhibits "dun" mould. Sen and Lahiry (1964) used a potassium sorbate dip before drying to extend the storage life of sun dried mackerel, while Phillips and Wallbridge (1977) in *in vitro* experiments have shown that sorbic acid at a concentration of 0.04 percent inhibited three *Aspergillus* spp. isolated from dried fish. Doesburg *et al.* (1969) found that dipping with sorbic acid after salting improved its effectiveness as sorbic acid appeared to be degraded by fish enzymes if added with the salt.

Propionic acid and combinations of propionic and acetic acids have been used effectively as mould inhibitors on moist grains, and Phillips and Wallbridge (1977) demonstrated *in vitro* that 0.1 percent propionic acid inhibited *A. amstelodami*, *A. chevalieri* and *A. ochraceus* isolated from cured fish products, although the flavour changes caused if products were treated in this may make them unacceptable for human consumption. As benzoates can be degraded by moulds and bacteria, sorbic acid may be the most suitable preservative for use in cured fish as it does appear to be stable in the products (Boyd and Tarr, 1955; Doesburg *et al.*, 1969). Sorbic acid has not been sufficiently investigated for it to be recommended on a commercial basis, and suitable application methods and required levels have yet to be established. No work appears to have been done on treating cured fish with acetic acid.

4.6 Sterilization of Cured Fish

Sterilizing products and packaging them in such a way that recontamination by micro-organisms is prevented is a well established technique, and is the basic principle behind the canning process. Cured products are inevitably exposed to recontamination and so the

sterilizing effect of cooking such as with hot smoking, even if total sterilization could be achieved, can only provide short-term preservation. Similarly, storing cured products at elevated or reduced temperatures will only inhibit growth while these temperatures are maintained, and only a sufficiently low Aw will ensure long-term preservation. Gonzales (1978) has shown that gamma irradiation may extend the storage life of cured products due to its sterilizing effect, but the short-term benefits of sterilization and the high cost of processing and packaging to prevent recontamination may mean that this approach will be of little commercial use in cured fish preservation.

4.7 The Storage Life of Cured Fish

Several factors determine the storage life of cured fish such as the Aw and pH of the product, temperature of storage, degree of smoking and microbial load, but for traditional dried products processed and stored under the usual conditions it is the Aw which is the major factor in determining if (or how quickly) micro-organisms will grow. The inhibitory effect of a reduced Aw which is not sufficiently low to ensure that all microbial growth is prevented, coupled with the fact that it takes a finite time for micro-organisms to cause spoilage, means that the Aw need only be reduced to ensure that the product is sufficiently well preserved to prevent spoilage during its maximum storage life. There is not necessarily any advantage in reducing the Aw to levels which will ensure long-term preservation, but the Aw should be matched as closely as possible to the required maximum storage life.

In a series of investigations, the results of which are to be published shortly (Doe *et al.*, unpublished; Poulter, Doe and Olley, unpublished) there has been an attempt to predict the minimum shelf-life of salted and/or dried fish from its salt and water contents under ambient temperatures and humidities. Using this information to calculate the Aw of the product, together with known germination times for moulds at different Aw levels it should be possible to estimate a minimum period free from mould growth.

Poulter (1980a) tested the concept by storing 7 samples of salted dried fish-dried fish and 2 samples of smoked fish for up to 33 weeks under simulated commercial storage conditions in Sri Lanka. The salt and water contents were measured at regular intervals and quality changes in the samples were assessed visually. The theoretical minimum mould-free storage period for each of the samples calculated by reference to the estimated Aw was correlated with the actual mould-free storage life of the samples. In every case the latter was greater than the former indicating that the concept appeared to be valid. Details of the relationships between composition and storage times are given in Table 8.

5. LOSS CAUSING INSECTS AND MITES

5.1 Introduction

In the early stages of curing, fish are generally susceptible to infestation from the larvae (maggots) of several species of fly (Diptera). More fully or completely cured fish are known to be attacked by a rather wider range of pests which include two species of fly, a species of mite and the adults and larvae of certain beetles.

The life cyles of all the insects mentioned involve four different stages, the egg, larva, pupa and adult. The adult females, after copulation, lay eggs, and from these hatch small active larvae that feed voraciously and develop rapidly. Most damage and loss is caused by the larval stage. After several moults the full-grown larvae develop into pupae, from which the adults finally emerge. In appearance the adults are quite different from either larvae or pupae and in comparison with the larvae they feed little. The life cycle of mites is discussed later in this chapter.

The development of insects and mites on fish is affected by several factors. If any of these factors are unfavourable then development may be slowed or even become impossible. Other sources of food such as fish waste and offal act as insect breeding grounds and greatly aid infestation under unhygienic conditions.

Table 8

Rough guide to the good quality storage life of dried fish with different water and salt contents

Water content (%)	Salt content (% wet wt)	Minimum "good quality" storage life
40	5	½ week
40	10	1 week
40	15	3 weeks
40	20	1½ months
35	5	½ week
35	10	2 weeks
35	15	2 months
35	20	1½ months
30	5	½ week
30	10	1½ months
30	15	2 months
30	20	2 months
25	5	1 week
25	10	2½ months
25	15	2 months
25	20	2 months
20	5	3 weeks
20	10	4 months
20	15	4 months
20	20	3½ months
15	5	More than 1 year
15	10	" " 1 year
15	15	" " 1 year
15	20	" " 1 year

Source: Poulter, 1980a

5.2 Infestation of Fish Early in the Curing Process

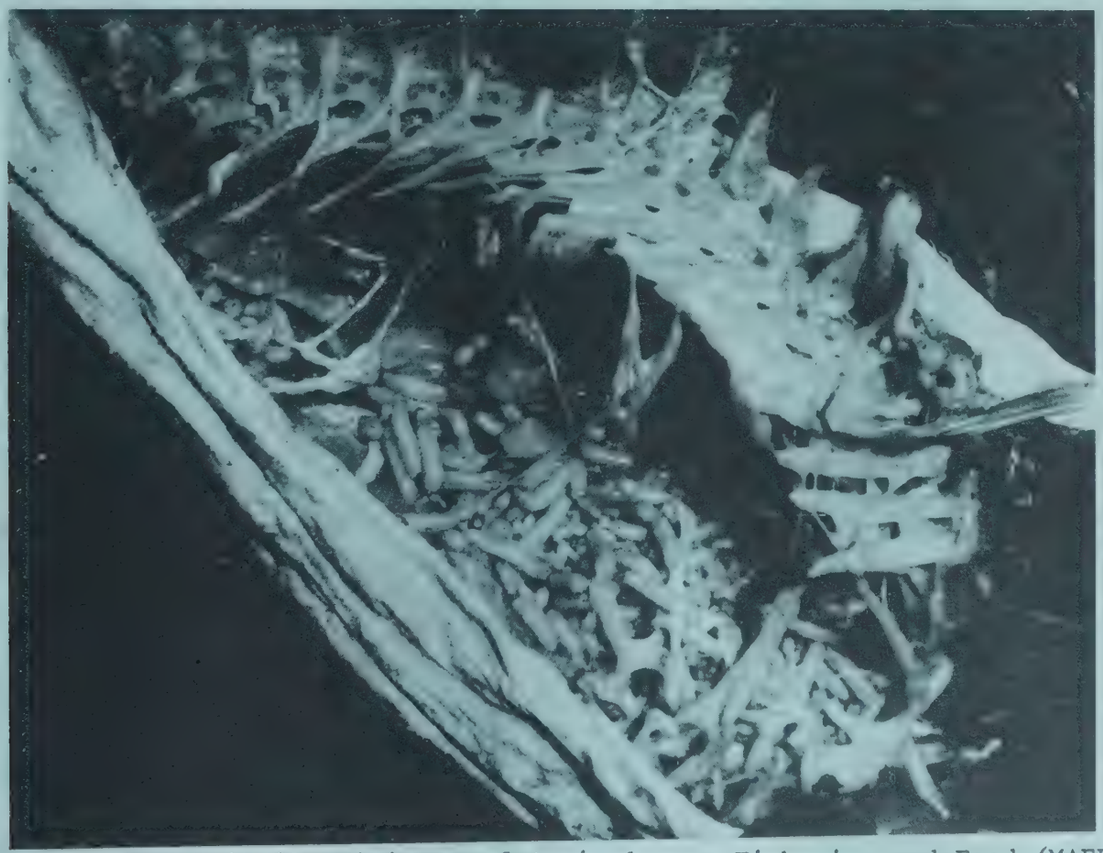
5.2.1 Characteristics of the Diptera (flies)

The flies found infesting moist fish (see Table 9, Part I) are all broadly similar in appearance. The adults measure 2.5-15 mm, have two large eyes and possess only two wings. Just behind each of these there is a small club-like structure called an haltere (Imms, 1977). The larvae are generally greyish-white, cylindrical in shape and usually taper, to variable extents, from the tail. The head is small and difficult to see, while the mouth parts are represented by two darkish hooks which may be completely retracted into the head. Lacking limbs, the larvae move by crawling, but are sufficiently mobile to spread infestation.

No convenient keys are available for the identification of adults or larvae of the Diptera which infest fish, so for all identifications a specialist entomologist should be consulted.

5.2.2 Details of life cycles and behaviour of Diptera

Adult female flies of the species mentioned in Table 9 Part I) lay eggs (or instead deposit small larvae) in batches on moist fish, especially in the mouth and gills (Meynell, 1978a). When the larvae hatch they move around freely on the surface or in the body cavity (Figure 1). The larvae congregate in "feeding areas" and may also make deep burrows into the flesh (Meynell, 1978a). This may cause the fish to break up and make it more prone to subsequent infestation by other pests, especially *Dermestes* spp. To pupate, the larvae usually leave the fish and may, for example, burrow into the earth beneath the drying fish. When the adults emerge from the pupae, nearby moist fish will be exposed to infestation, thus continuing the cycle.



Source: Great Britain, Ministry of Agriculture, Fisheries and Food (MAFF)

Figure 1 - Blow-fly larvae infesting moist fish

Table 9

Insect and mite pests of fish

Part I - Attacking fish early in the curing process

INSECTA	Known distribution	Region of recorded infestation	Reference
Diptera Cyclorrhapha Calliphoridae			
Chrysomya abliceps Weidemann[a/]	Tropical	Malawi	Meynell (1978a)
Chrysomya chloropyga putoria Weidemann[a/]	Tropical	Malawi	Meynell (1978a)
Chrysomya regalis Desvoidy (=*C. marginalis* Weidemann)[a/]	Tropical	Malawi Uganda Zambia	Meynell (1978a) McLellen (1963) Proctor (1972)
Lucilia sp.	Cosmopolitan	Bangladesh	Ahmed *et al.* (1978)
Wohlfartia spp.	Cosmopolitan	Aden	Cole (1963) Green (1967)
Ephydridae			
Discomyza maculippenis Weidemann (found on rotting fish)	Widespread	India	Soans & Adolph (1971)

[a/] Species considered to cause significant losses

Table 9 (cont'd)

Part II - Attacking fish late, or after the curing process

INSECTA	Known distribution	Region of recorded infestation	Reference
Diptera			
Cyclorrhapha			
Piophilidae			
Piophila casei (Linnaeus)	Cosmopolitan	Malawi	Nyasaland Protectorate (1963)
Milichidae			
Leptometopa latipes (Meigen)	Widespread	India	Pillai (1957)
Coleoptera			
Dermestidae			
Dermestes maculatus Degeer (=*D. vulpinus* Fabricius)a/	Cosmopolitan	Throughout tropics	Hinton (1945)
Dermestes frischii Kugelanna/	Cosmopolitan	Throughout tropics	Hinton (1945)
Dermestes ater Degeer (=*D. cadaverinus* Fabricius)b/	Cosmopolitan	Indonesia Aden Zambia S. India	Kalshoven (1954) Green (1967) Proctor (1972) Pillai (1957)

(cont'd)

Table 9 - Part II (cont'd)

INSECTA	Known distribution	Region of recorded infestation	Reference
Dermestes carnivorus Fabricius	Cosmopolitan	Indonesia Philippines	TPI, unpublished Ahmed *et al.* (1978)
Cleridae			
Necorbia rufipes (Degeer)b/	Tropical	Throughout tropics	Aitken (1975)
ARACHNIDA			
Acarina			
Astigmata			
Acaridae			
Lardoglyphus konoi (Sasa and Anasuma)b/	Cosmopolitan	Throughout tropics	Pillai (1957) Sasa (1964) Hughes (1976)

a/ Species considered to cause significant losses

b/ Species that might possibly cause significant losses

The adult flies themselves are attracted to and feed upon rotting material (especially fish offal) and dung where they may feed and breed. In this way they spread pathogenic bacteria when egg-laying on fish and therefore present a health hazard. They may also transfer mites such as *Lardoglyphus konoi* to the fish (Pillai, 1957).

In the wet season in Malawi, Meynell (1978a) found that the life cycle for *Chrysomya* spp. was very rapid, the eggs hatched about one day after laying, and the larval stage was completed in three to four days.

5.3 Infestation of Partially and Fully Cured Fish

5.3.1 Characteristics of the pests

Those species that will attack more fully cured fish are listed in Table 9 (Part II). The greatest damage, of the type shown in Figure 2, is caused by the *Dermestes* spp. (see chapter 3), but certain other insects and mites, more often associated with other stored products such as cereal grains and flour, may also be found on fish. As these species are not specific pests of cured fish, occur on fish rarely, and are unlikely to cause significant losses they will not be dealt with here.

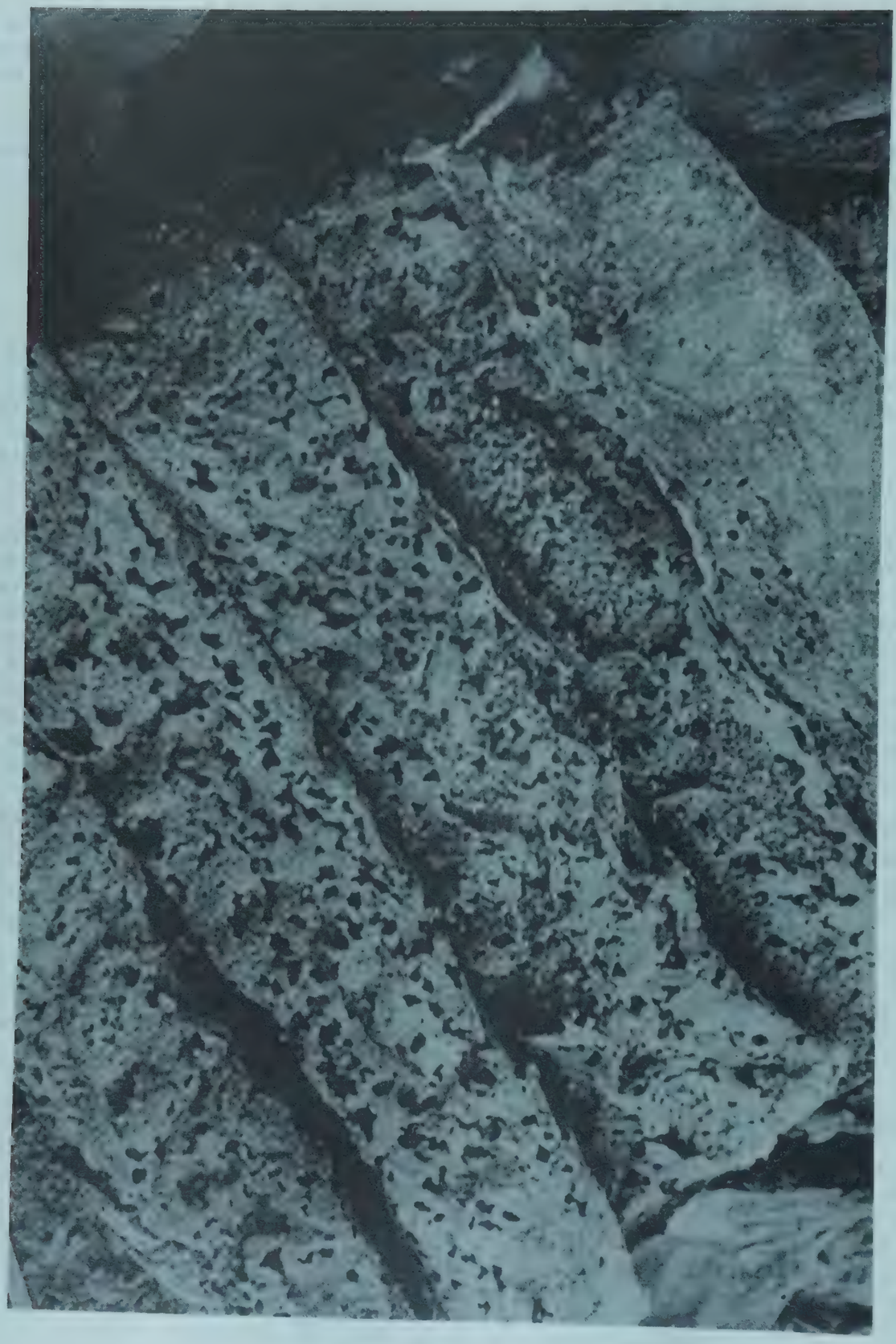
Coleoptera (Beetles): Beetle larvae differ from those of flies in having three pairs of legs, a distinct head and by being more or less hairy (Figures 3 and 4). The larvae of *Dermestes* spp. are very hairy (Figure 3) and at the posterior end of the body possess two spines (urogomphi). When newly hatched the larvae measure 1.5 mm, and on reaching maturity measure about 15 mm. The larvae of *Necrobia rufipes* (Figure 4), another common beetle pest of fish, is similar in size to that of *Dermestes* spp. but is much less hairy and is creamish grey with patches of mottled grey. Adult beetles (Figures 5, 6 and 7) may be recognized by their outer wing cases (elytra). A key has been provided (Table 10) for the identification of the adult beetles that commonly infest fish products. A detailed account of the adults and larvae of *Dermestes* spp. is given in Hinton (1945).

Diptera (flies): *Piophila casei* (described in detail by Simmons, 1927) and *Leptometopa latipes* are apparently the only species of fly recorded infesting cured fish. Adults of both species are 2.5-4 mm long; the form of both adults and larvae is typical of that already described for the Diptera in this chapter. The behaviour of the larvae of *P. casei* is unusual in that they are able to leap. To do this the hooks of the mouth are used to grasp the posterior end and the abdominal muscles are tensed.

When the hooks are released the larva is flung into the air. No identification key is available for these flies, and so for identifications a specialist entomologist should be consulted.

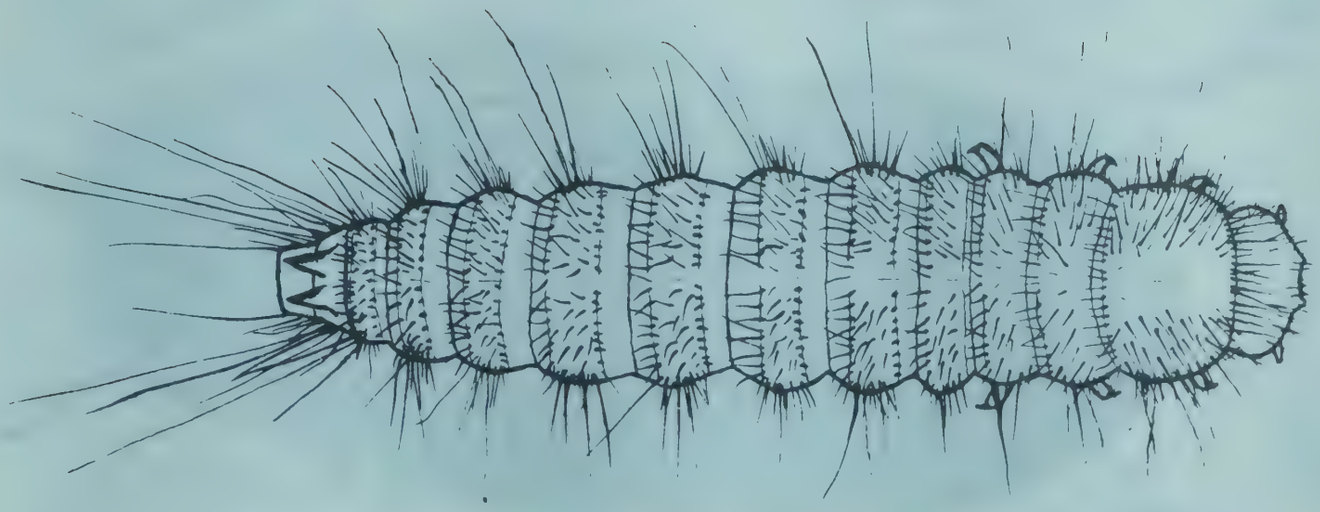
Acarina (mites): Mites have small globular bodies that are generally translucent and rather hairy. The adults measure up to 0.5 mm long and have four pairs of legs. The identification of mites is very difficult owing to their small size and to the superficial similarity between the various species. After copulation the adult females lay eggs from which tiny 6-legged larvae hatch. Each larva moults to become an 8-legged nymph which itself moults several times before developing into an adult. In numerous mite species one of the nymph stages, called the hypopus, is specialized for dispersal or survival under adverse conditions. The hypopi, unlike the other developmental stages, do not feed and their dispersal may be achieved by clinging to bodies of other animals particularly the adults and larvae of *Necrobia rufipes* and *Dermestes* spp. (Hughes, 1956; Pillai, 1957; Chmielewski, 1977).

Only one species of mite, *Lardoglyphus konoi* has been commonly associated with cured fish.



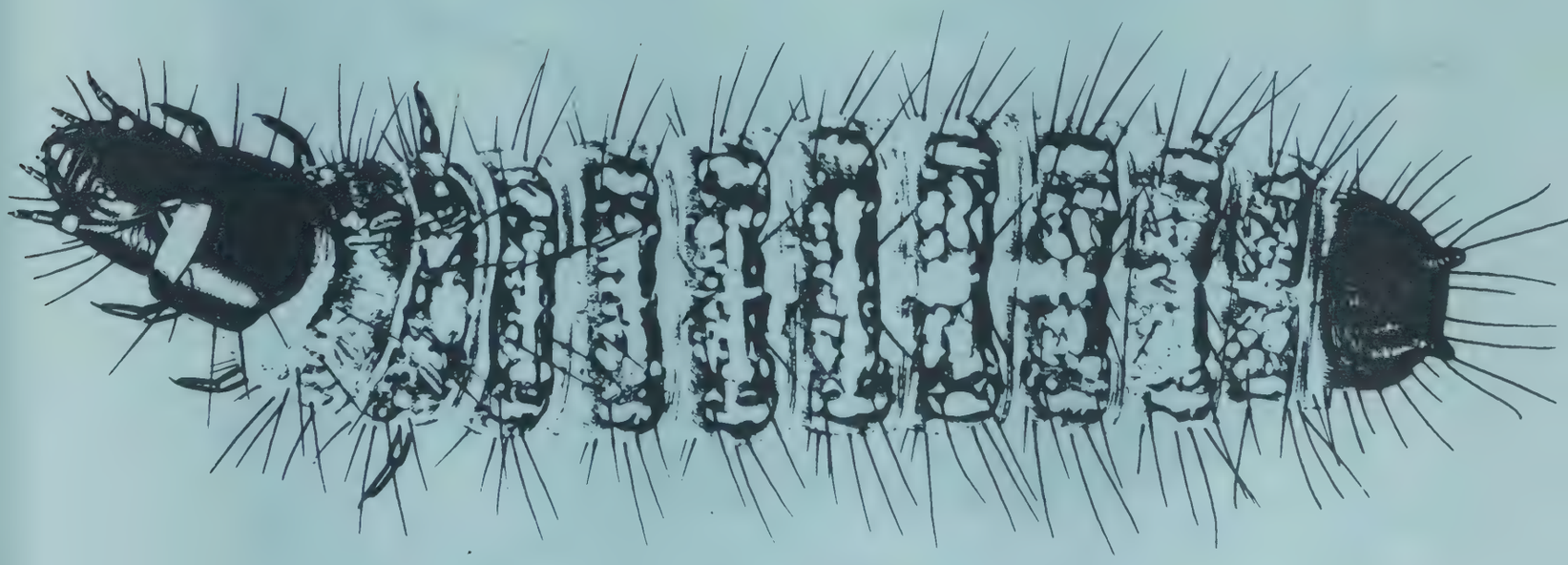
Source: Journal of Stored Products Research

Figure 2 - Dried shark damaged by *Dermestes frischii*



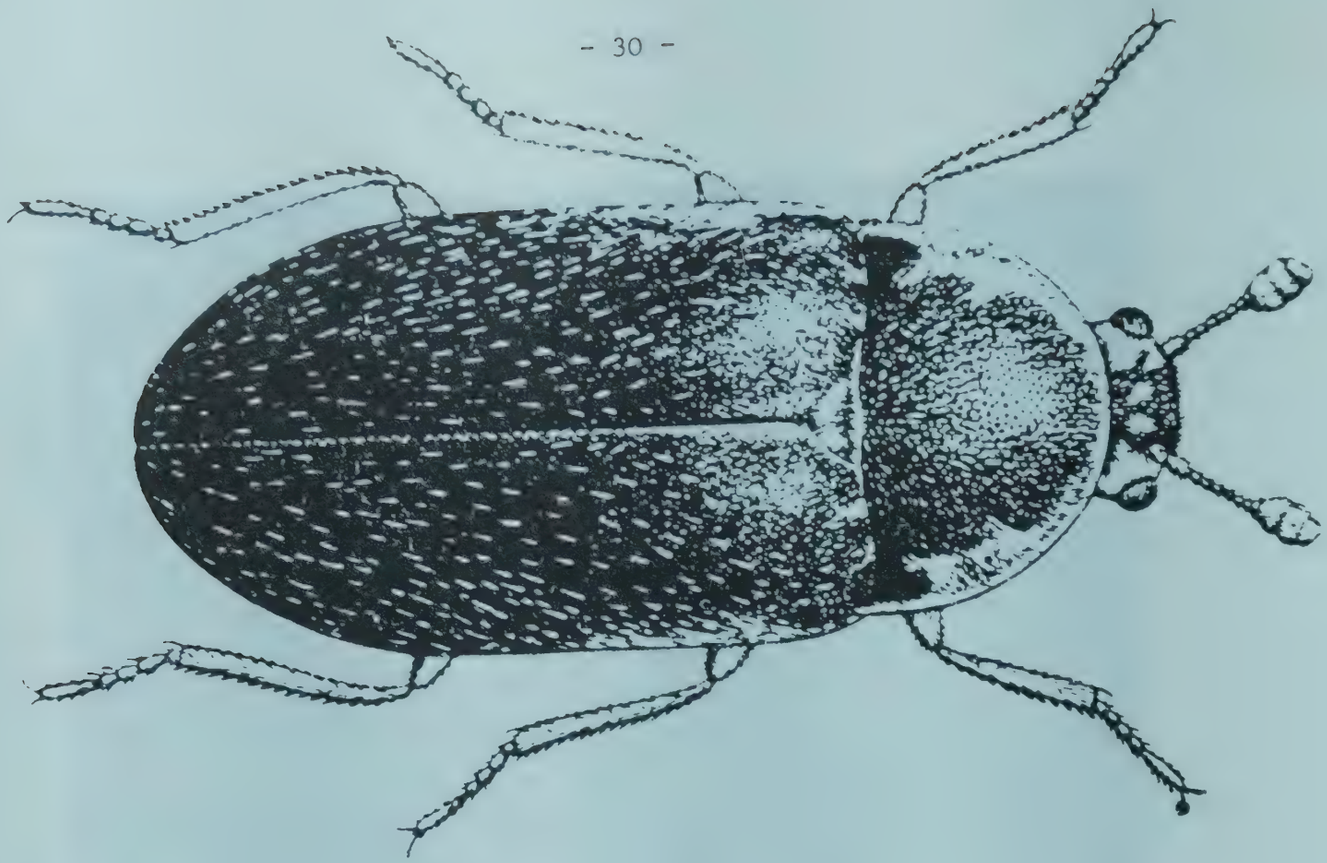
Source: Great Britain, Ministry of Agriculture, Fisheries and Food (MAFF)

Figure 3 - Dorsal view of the larva of *Dermestes* spp. (x 4)



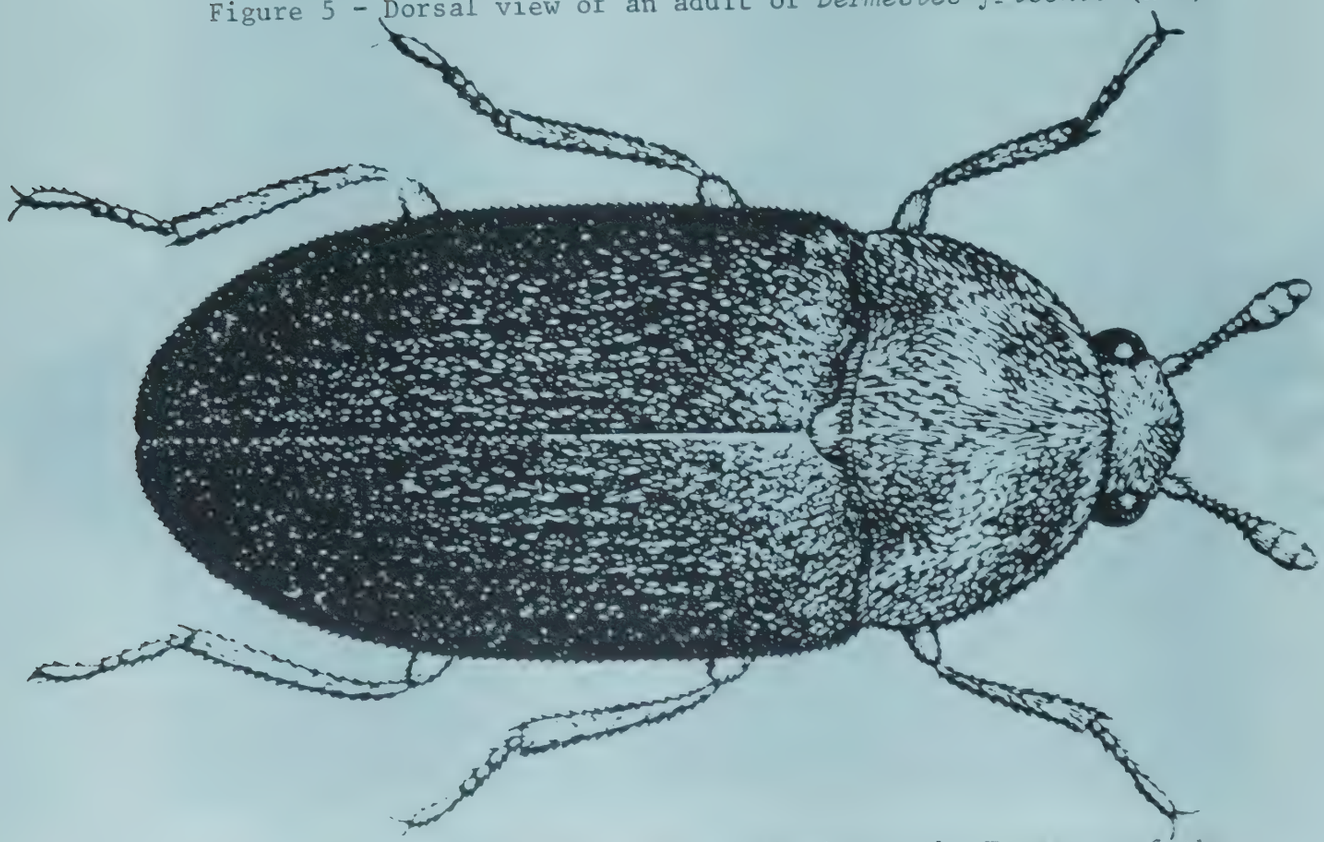
Source: Great Britain, Ministry of Agriculture, Fisheries and Food (MAFF)

Figure 4 - Dorsal view of the larva of *Necrobia rufipes* (x 6)



Source: Hinton and Corbet, 1975; Thanks to the Trustees of the British Museum of Natural History

Figure 5 - Dorsal view of an adult of *Dermestes frischii* (x 7)

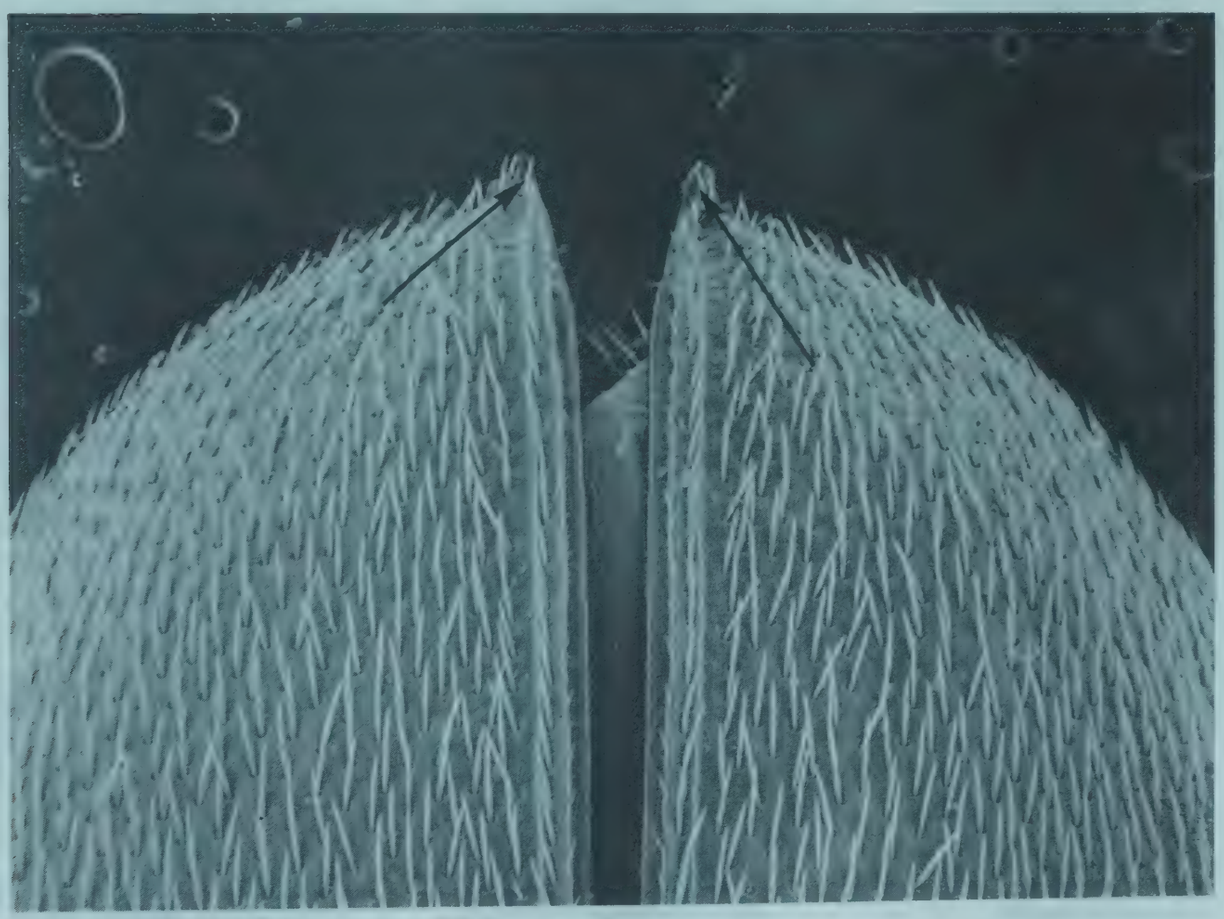


Source: Hinton and Corbet, 1975; Thanks to the Trustees of the British Museum of Natural History

Figure 6 - Dorsal view of an adult of *Dermestes ater* (x 7)

Source: Great Britain, Ministry of Agriculture, Fisheries and Food (MAFF)

Figure 7 - Dorsal view of an adult of *Necrobia rufipes* (x 6)



Source: Tropical Products Institute

Figure 8 - A scanning electron micrograph showing the apical spines (arrowed) on elytra of *Dermestes maculatus* (x 25)

Source: Hinton and Corbet, 1975; Thanks to the Trustees of the British Museum of Natural History

Figure 9 - The ventral abdomen of a male *Dermestes frischii*, showing brush of hairs (arrowed) (x 25)

Source: Hughes, 1976; Thanks to Her Majesty's Stationery Office, London

Figure 10 - Dorsal view of an adult female *Lardoglyphus konoi* (the legs have been drawn on only one side of the body) (x 110)

Table 10

Identification of the adults of the five major beetle species infesting fish products

The identification key below consists of four pairs of statements (couplets) numbered 1 to 4. Start the Key at Couplet 1. Read both statements in the couplet and decide which is true for your specimen. At the end of the correct statement there will either be the name of the species concerned, in which case the identification is complete, or a number indicating the next couplet required to continue the identification. If you arrive at a couplet in which neither statement applies to your specimen then seek the advice of an entomologist.

1. Cuticle of dorsal surface reddish brown/black and covered in black and grey, or golden hairs. Length 6-10 mm. Antennae less than half the length of the front legs and with the apical three segments forming a compact club.

   Resembling Figure 5 or 6 2

\- Cuticle of dorsal surface entirely metallic blue-green. Length 4-5 mm. Antennae more than half the length of the front legs, yellowish-red in colour and with a distinct dark brown or black club. Apical antenna[1] segment not longer than broad. Legs entirely yellowish-red .... *Necrobia rufipes* Degeer (Figure 7)

2. Wing case with a distinct sharp spine at apex (Figure 8) .... *Dermestes maculatus* Degeer

\- Wing case rounded at apex 3

3. Abdomen ventrally mostly covered with white hairs but with some black patches 4

\- Abdomen ventrally mostly covered with golden brown hairs but with patches of red-brown hairs just each side of the mid-line and some more laterally ..... *Dermestes ater* Degeer (Figure 6)

4 Abdomen ventrally with black patches both laterally and at the posterior tip (Figure 9). Males only, with a distinct brush of hairs on the fourth abdominal segment (Figure 9) .... *Dermestes frischii* Kugelann (Figure 5)

\- Abdomen ventrally with black patches laterally but without a black patch at the posterior tip. Males only with a distinct brush of hairs on both the third and fourth abdominal segment .... *Dermestes carnivorus* Fabricius

Lardoglyphus konoi: A female specimen is illustrated in Figure 10. Adults measure 0.3-0.55 mm long, with the male being somewhat smaller than the female. Males also differ in that each of the legs of the third pair terminates in two stout spines rather than a single claw which is the case with all other legs of the male or female. For a more detailed description of this species consult Pillai (1957) or Hughes (1976), the latter providing appropriate identification keys.

5.3.2 Detailed life cycles and behaviour

Coleoptera: Several workers (Scoggins and Tauber, 1951; Monteiro-Guimares, 1956; Paul *et al.*, 1962; Azab, Tawfik and Abouzeid, 1972, a; Osuji 1975b) have undertaken general studies on *D. maculatus*. This species appears to infest freshwater fish more frequently than marine fish (Mallamaire, 1957), this aspect being discussed in more detail later. Within 12 to 40 hours of copulation females lay oval-shaped eggs (1.3 mm long and 0.35 mm in diameter) in the cracks of the body wall muscles of the drying or dried fish. For regular egg-laying (oviposition) activity the females must have access to a supply of moisture. Females may lay an average of 17 eggs per day, over a period of about 14 days (Osuji, 1975b). Paul *et al.* (1962) found that at temperatures of 25°C, 30°C and 35°C the development of eggs into larvae was completed on average in 3.5, 2.0 and 1.5 days, respectively with a hatching success of about 50 percent.

The optimum temperature for larval development lies between 30° and 35°C (Howe, 1965). On a diet of dried meat at 35°C and 75 percent rh development is completed in an average of 20 days (Azab, Tawfik and Abouzeid, 1972a), but the rate of larval development is known to be affected by several factors. Under unfavourable conditions there is an increase in the larval period and consequently an increase in the number of larval moults from 5 to as many as 11 (Azab, Tawfik and Abouzeid, 1972a). Cast larval skins are commonly found in infested fish and are easily confused with the larvae.

To pupate, the larvae burrow into available solid substrates such as the muscle tissue of dried fish itself or timber supports. The larvae then become shorter, thicker and quiescent, and finally moult to become pupae. The shed skin of the larva will often remain around the pupa. At 27°C the pupal period lasts for about 6 days and under optimal conditions the numbers of *D. maculatus* can increase by a factor of 30 in a 4 week period (Howe, 1965). The adults can fly and may use their wings as well as legs as an effective means of dispersal.

The life cycle of *D. frischii* has been studied by Howe (1953) and Amos (1968) and found to be generally similar to that of *D. maculatus*. The species has been more frequently recorded on dried marine fish (Mallamaire, 1957; Green, 1967), a finding which may be due to a higher tolerance of salt than *D. maculatus* (discussed later in this chapter). Male and female *D. frischii* may copulate several times during their lives starting soon after emergence. There is a pre-oviposition period which may be as short as two days when the insects are maintained at 30°C and 75 percent rh. The females lay an average of 130 eggs over a 50 day period, the vast majority being deposited during the first 25 days. The eggs are laid in a food source, and as is also the case with *D. maculatus*, the females must be able to drink water if they are to reach their full reproductive potential. At 30°C and 75 percent rh full development of the egg takes from two to four days. It was found that when newly hatched larvae were fed on fishmeal they reached the pupal stage within an average of 25 days. The pupal period lasted some 6 days, making the mean period for development a total of 34 days.

The adults are known to fly freely at dusk but usually shelter during day time under fish. Infestation may result directly from adult oviposition on the fish or by the migration of larvae which have either been disturbed or are looking for fresh food (Green, 1967).

Dermestes ater has frequently been found infesting copra but has also been recorded infesting cured fish (Table 9, Part II). It is usually a relatively minor pest compared with either *D. maculatus* or *D. frischii* but under certain conditions, on dried anchovies in southern India for example, losses of between 10 and 15 percent have been recorded (Pillai, 1957). On a diet of fish meal with a little wheat germ, yeast and cholesterol at 30°C and 65 percent relative humidity, the mean period for complete development for males was 40 days and females 42 days (Coombs, 1981). Under ambient conditions in Indonesia on a diet of unsalted dried fish the mean period was 46.5 days (Kalshoven, 1954). The adults possess wings and may remain airborne for as long as 5 minutes (Pillai, 1957) probably affording the species a good means of dispersal.

Very little is known about *Dermestes carnivorus*. It has been recorded infesting dried fish in Indonesia and the Philippines (Table 9, Part II), but it does not appear to be a major pest.

Necrobia rufipes is a well known pest of copra and is also frequently found on dried fish. Its biology has not been studied in detail on dried fish but only on copra (Costa, da, 1955) and on a mixed copra and fish meal medium (Ashman, 1962). Pillai (1957) states that both copra and cashewnuts are more favourable diets for *N. rufipes* than dried fish, but in a brief study Osuji (1977) found dried fish to be more suitable than either copra, groundnuts or palm kernels. The type and condition of the fish in the two studies was probably different and this may account for the varying results.

Adult *N. rufipes* feed only superficially on dried fish but the larvae burrow deep into the flesh. The larvae are also predators and may kill and eat the larvae of *Piophila casei* (Ashman, 1962) or the eggs and larvae of *Dermestes* spp. (Simmons and Ellington, 1925). The optimum temperature for development is between 30 to 34°C (Howe, 1965). There are three or four larval moults after which the fish may be left for a dark crevice where a cocoon can be built for pupation. Under the ambient conditions of southern India and on a diet of dried fish, development is completed in 41-69 days (Pillai, 1957). Under optimum conditions the species may increase about 25-fold in a period of four weeks (Howe, 1965). The adults are active fliers and disperse themselves very effectively by this method.

Diptera (flies): The life cycle of *Piophila casei* is broadly similar to that of other Diptera. The larvae burrow deep into the fish flesh, and under ambient conditions in Malawi the life cycle on dried fish is completed in 19-23 days (Nyasaland Protectorate, 1963). Nothing is known about the life cycle of *Leptometopa latipes* on dried fish.

Acarina (Mites): The life cycle of *Lardoglyphus konoi*, which includes an hypopal stage for dispersal, is very rapid under suitable conditions for example at 23°C and 87 percent relative humidity on dried heart muscle, it is completed in only 9-11 days (Hughes, 1976). Matsumoto (1970) indicated that the optimum conditions for development are 30°C and 87 percent relative humidity. Infestations of *L. konoi* have been associated with those of *Dermestes* spp. and *Necrobia rufipes* (Hughes, 1956; Pillai, 1957; Pointel and Pham Van Sam, 1969). Although this may in part be due to a general similarity of these pests in their physical and nutritional requirements, the mite's hypopal stage is known to cling to the bodies of adult beetles and in this way they reach the same food source.

5.4 Factors Affecting Infestation

5.4.1 Temperature

Insect and mite development will only occur within certain specific temperature limits. For each species there is an optimum temperature for development, although this temperature has only been determined for a few species.

When *D. maculatus* was maintained on dried meat at 75 percent relative humidity and an optimum temperature of 35°C, larval development took only 20 days. At the suboptimal temperature of 21°C this period was increased to 53 days (Azab, Tawfik and Abouzeid, 1972a). Development of *D. maculatus* (Howe, 1965) and *D. frischii* (Amos, 1968) is not possible below 20°C, and for *D. ater* the limit is 21°C (Coombs, 1981).

Temperatures above the optimum have severe effects and can be used for disinfestation. Although relatively little work has been done on the effect of temperature on adult flies and their larvae, it has been noted by Doe *et al.* (1977) that temperatures in excess of 45°C decreased infestation by blow-fly larvae although 20 hours at this temperature was required for a complete kill. Of special note is the relatively high resistance of *Piophila casei* to elevated temperatures. Smart (1935) found the larvae able to withstand 1 hour at 52°C and 24 hours at 45°C, but in contrast the pupal stage was killed by exposure to 37°C.

In the *Coleoptera*, ambient tropical temperatures have been reported to affect the behaviour of *D. maculatus* and *N. rufipes* infesting stored dried fish. Osuji (1975c) noted that during the day, as the ground surface temperature rose to about 50°C, the insects migrated to the inside of fish heaps where the temperature reached only 35°C. Thus a marked daily migration of larvae and adults to avoid excessive temperatures was observed. In *D. maculatus* (Paul *et al.*, 1962) and *D. frischii* (Amos, 1968) development is not possible at 40°C or above. Furthermore, *D. maculatus* larvae are killed by exposure to temperatures of 50°C for more than 15 minutes (Paul *et al.*, 1962) although 40 mins at 70°C was reportedly required to disinfest cured fish (FAO/PNUD, 1970). No work appears to have been conducted on the lethal temperatures for other *Dermestes* spp. or *N. rufipes*.

5.4.2 Moisture content and relative humidity

Insects and mites typically select conditions of rh and food moisture content which favour their development. For successful development *N. rufipes* must have an rh of 50 percent or above (Howe, 1965), and *D. maculatus* tends to prefer similar conditions. Toye (1970), using humidity gradients, showed that adults and larvae of *D. maculatus* select an rh of between 60 and 80 percent, and that within this range the adults tended to select somewhat higher humidities than the larvae. Such a selection would have significant effects on the development rate as Azab, Tawfik and Abouzeid (1972a) found that on a diet of dried unsalted fish at 27°C an increase in rh from 55 to 75 percent decreased the length of the average larval period from 35 to 28 days. Scoggins and Tauber (1951) investigated the effects of various moisture contents on the development of larvae fed on sardine fish meal at 32°C and 75 percent rh. Moisture contents as low as 7.5 percent or as high as 46 percent were unfavourable and induced high (approximately 50 percent) mortalities while moisture contents of 10.5 and 15.9 percent were both very favourable for development and resulted in mortalities of only about 4 percent. Thus the usual moisture contents of unsalted dried fish products are very favourable to the development of *D. maculatus*, but in contrast well dried fish are more resistant to this species.

The requirements of other pests of fish are less well known. The diptera infesting fish in the early stages of drying must be sensitive to moisture content as their ravages become progressively less important as the fish dries until it is no longer suitable food for them (see chapter 3). In the case of the mite *L. konoi* it has been observed that infestation of dried fish is much more severe in the rainy season when thorough drying of the fish is difficult (Pillai, 1957). The moisture and humidity preferences and limits of the flies infesting dried fish, *Piophila casei* and *Leptometopa latipes* are not known, but development of the latter is more rapid on fish that has been poorly dried (Pillai, 1957).

It has been observed that there are peaks in pest numbers at certain times of the year (Pillai, 1957; Green, 1967). These seasonal peaks almost certainly occur when the ambient temperature and humidity coincide with the optimum conditions for pest development, for instance wet seasons favouring blow-flies.

5.4.3 Food type

Except for *Dermestes* spp. little or nothing is known about the dietary requirements of fish pests. *Dermestes* spp. are unusual in having rather specific sterol requirements as food for *D. frishii* must contain cholesterol, while *D. maculatus* is dependent on dietary cholesterol or a closely related sterol (Woodroffe and Coombs, 1979). Thus these two species generally only develop on food containing cholesterol, that is animal products. *D. ater* is more adaptable and is able to infest some vegetable products notably copra. Thus when fish and plant products are stored together cross-infestation by *D. ater* is possible.

There is some variation in the susceptibility of different fish genera to infestation by *D. maculatus* (Azab, Tawfik and Abouzeid, 1972a; Osuji, 1974), *N. rufipes* (Osuji, 1974) and *L. konoi* (Vijayambike and John, 1975). For example in the case of *D. maculatus* Azab, Tawfik and Abouzeid (1972a) found that at 27°C and 75 percent rh larval development on dried *Tilapia* took on average 29.4 days, while on dried *Sardinella* the average rose to 42.7 days. The

difference in the suitability of various fish genera for the development of insect infestation has been noted in chapter 3, but as yet no satisfactory explanation has been given for the differences. For the mite *L. konoi* a possible explanation has been found. Vijayambike and John (1975) determined the moisture content, protein and fat of several species of dried fish, and then allowed samples to become infested with *L. konoi*. It was concluded that the fat content of the fish was the most important of these factors, higher levels facilitating greater infestation.

5.4.4 Salting of fish

Most fish pests are known to be adversely affected by salting. Heavy salting appears to provide complete protection from fly larvae (see chapter 3). No details of the effect of lower salt levels are known and the effects of salt on *Piophila casei* and *Leptometopa latipes* seem not to have been investigated, although the latter species finds the infestation of salted dried tuna difficult (Pillai, 1957).

D. frischii appears relatively tolerant of salt (Amos, 1968), but at 30°C and 75 percent rh the addition of 14 percent salt to a diet of fish meal increased the mean total development period from 34 days to 42.2 days, and the addition of 25 percent salt increased the time still further to 53 days. The number of eggs laid was reduced in the presence of salt, and it is this factor combined with a lower development rate which drastically slows the population increase. Amos (1968) calculated that the population increase per week at 30°C and 75 percent rh would be 97 percent with no salt, 45 percent with 14 percent dietary salt and as low as 3 percent per week with 25 percent salt.

Kalshoven (1954) studied *D. maculatus* and *D. ater* fed on slightly salted meat. He noted that under these conditions the adult longevity was reduced, and that the number of larval moults and the development time were considerably increased. *D. maculatus* is somewhat more inhibited by salt than *D. frischii*. Mushi and Chiang (1974) and Osuji (1975a) found that larval development in *D. maculatus* was impossible on fish meal with a salt concentration of only 10 percent. This may account for the less frequent occurrence of *D. maculatus* in marine fish, as salt is usually more readily available for (and in general more widely used in) marine fish processing.

The larval development of *N. rufipes* is severely retarded on fish with a 3.5 percent salt concentration and 9.9 percent moisture content being on average 85.0 days compared with 42.0 days in the unsalted control (Osuji, 1975a). Pillai (1957) has noted that prawns cured in a 15 percent salt solution were resistant to infestation by *L. konoi*, although brining in 2.5 and 5 percent salt solutions also gave some protection.

Hence adequate salting of fish will provide good protection from insect infestation.

5.5 Radiation Disinfestation of Dried Fish

There have been several studies on the use of ionizing radiation for the disinfestation of dried fish (Aref, Timbely and Daget, 1965; Daget, 1966; Boisot and Gauzit, 1966; Pointel and Pham Van Sam, 1969; Ahmed *et al.*, 1978). The method involves irradiating the fish with a dose high enough to sterilize and drastically shorten the lives of any insects present, further infestation being prevented by placing the fish in an 'insect proof' container.

The only fish pest for which radiation disinfestation has been studied in detail is *D. maculatus*. Pointel and Pham Van Sam (1969) found that 10-30 Krads was sufficient to reduce longevity of all stages in the life cycle and prevent reproduction. Ahmed *et al.* (1978) studied the radiation disinfestation of dried mackerel, but unfortunately in none of their tests was the dose rate or temperature of treatment quoted. They found that 5 KR (for practical purposes 1 KR = 1 Krad) was sufficient to induce almost 100 percent sterility, however, for general use they recommend 20 KR for the disinfestation of fish wrapped in polythene (75 µm thick).

The treatment of fish with 20 KR is very unlikely to cause any deterioration in fish quality. Boisot and Gauzit (1966) studying 5 types of dried fish determined that exposure 20-500 KR produced no undesirable organoleptic changes. It is not certain that 20 KR is a suitable dose for the treatment of all pests of cured fish, but at least the radiation response of *D. frischii* and *D. maculatus* appear similar, the mortality of newly emerged adults 20 days after exposure to approximately 20 KR being 95 percent in *D. frischii* (Abdu and Shaumar, 1974) and 90 percent in *D. maculatus* (Pointel and Pham Van Dam, 1969).

The relative sophistication of the equipment required may well hinder the commercial development of radiation disinfestation. Further, other disinfestation techniques, such as fumigation and heat treatment, are available and could prove more appropriate for use in the majority of existing circumstances.

6. IMPROVED PRESERVATION AND PROTECTION METHODS

6.1 Sanitation and Hygiene

The need for basic cleanliness and hygiene cannot be over-stressed in the production of food products of any kind, and traditionally cured fish should certainly not be an exception. Various codes of practice and standards have been drawn up by FAO/WHO, and the "Recommended International Code of Practice - General Principles of Food Hygiene" as well as codes of practice on fresh, smoked and salted fish are all relevant (see References under FAO/WHO Food Standards Programme Codex Alimentarius Commission).

It must be appreciated that although adhering to these codes is advisable, in small remote fish landings which lack basic amenities many of the recommendations are impractical. It is, for example, better to cure an inferior quality fish and make admittedly poor products than just discard the fish as spoiled. It must also be stated that the spirit of many of the recommendations could be carried out even with just the most basic of facilities. Some of the more basic measures are noted below, but a very much more detailed list is given in the relevant Codex Codes.

a. Careful and rapid handling of fish to be cured, so that processing can start with the minimum of delay.

b. Ensuring that the fish processing area and equipment is kept clean, and is thoroughly washed with water (sea water if fresh water is unavailable) before processing starts and on completion.

c. Fish offal and other waste material should be removed from the processing site as quickly as possible and should never be allowed to accumulate. Discarding waste back into the water or incineration may be the most convenient means of disposal if no other is available.

d. Any salt used should be of a reasonable quality, and processing techniques should ensure that the end product is uniformly salted with no surface crystals.

e. Fences should be erected to exclude dogs, cats, and other domestic animals. Ideally such fences should also protect fish from rodents.

f. The use of raised fish drying racks will aid in the protection of fish from animals and some insects, as well as preventing contamination by dirt and dust.

g. Netting should be erected over the drying racks to exclude birds. Fly screens may be useful in preventing blow-fly infestation.

h. The careful use of appropriate insecticides under drying racks and in storage areas may be of help.

i. Storing cured fish in adequate weather-proof areas.

Such measures will reduce losses and improve the quality of the final product, but all too often even the most basic measures to improve hygiene are not performed.

6.2 Improved Processing Methods

6.2.1 Introduction of salt

In chapter 2 it was noted that salt was not used very widely in Africa, especially in the inland fisheries. Attempts have been made to introduce it principally to act against insect infestation, but these efforts have met with little long-term success (Moes, 1980). It has been a matter for debate whether this is primarily a dislike by cured fish consumers of salted fish or the fact that in these regions salt is expensive and the supply limited, or indeed a combination of the two factors as suggested by Mills (1979).

Watanabe and Dzekedzeke (1971) demonstrated that relatively lightly salted (8-9 percent salt in the final product) smoked fish was acceptable in Zambia, and suggested that the major reason why heavily salted products were unpopular was that they were unfamiliar to local people who did not realize that the fish had to be soaked in water prior to cooking. Cole (1975), also working in Zambia, found that some salted fish fetched higher market prices than unsalted, but that the lack of adequate supplies of salt ensured that the unsalted product was the most common. In contrast Beatty (1969) suggested that salted fish was not considered acceptable by the Zambians, but he did suggest that it was due to unfamiliarity and the conservative attitude of consumers rather than an intrinsic dislike of the product. In Uganda, Disney (1968) suggested that salt was used sparingly due to its high price, and there was no reported acceptability problems with salted products.

Heavily salted fish has been successfully introduced into inland Papua New Guinea, where it was previously not familiar (but neither were unsalted cured products). Potential consumers had been shown how to prepare the fish for consumption as part of the development programme (Glucksman, 1978). Mills (1979) suggested that very lightly salted (2-3 percent salt content) fish may be acceptable in the Lake Chad area even if more heavily salted products are not.

In conclusion it can be stated that although the picture is far from clear, there is some evidence that if an adequate and inexpensive supply of salt were available its use in processing would probably be of benefit. The increased use of salting may be slow until the salted products become familiar, but it does appear that the historical reason for the limited use of salt is a lack of supply rather than an intrinsic dislike of the product.

6.2.2 Improved salting

General considerations: Fish, especially large fish, must be properly split and dressed for salt to penetrate the flesh quickly (as outlined in chapter 2). The uniform application of sufficient salt is the objective of a salting process. Halophilic bacteria (see chapter 4) are inhibited by reduced temperatures, so keeping salting vats in the shade is advisable under tropical conditions.

Salt of medium crystal size should be used for dry salting to ensure salt penetration and moisture extraction proceeds at a reasonable rate. Food quality salt suitable for fish curing should be selected if available. Salt is often prepared in tropical countries by letting the heat of the sun evaporate sea water in an enclosed area. The salt which is collected by these means is often contaminated with sand, grit and minerals other than sodium chloride. Disney (1974a) has reported that some commercially available salt prepared by these means had sodium chloride contents as low as 52-88 percent. Chemical contaminants can certainly reduce the quality of the final product, may adversely affect salt penetration, and may also accelerate the oxidation of fish fat.

Salt is often contaminated with halophilic bacteria (Shewan, 1951) which can cause the losses described in chapters 3 and 4. Pure, bacteria-free salt is generally unavailable or too expensive, but careful control of salt production is highly desirable, and there is often considerable scope for improvement. Storing salt in a dry place has been recommended as a means of reducing its bacterial load (Cole, 1963).

Salting techniques: the basic salting techniques commonly in use were outlined in chapter 2. Brining (in particular) and pickling have some important advantages over kench curing as salting techniques under tropical conditions, the major one being that they generally lead to much more even salting. Salting can also be more uniform between batches. Covering the fish with brine affords some protection against attack from halophilic bacteria, insects, and rancidity. Although some traditional curers seem aware that fatty fish are best wet salted (Cole, 1963), presumably due to rancidity problems, there seems to be little awareness of the other advantages of wet salting techniques. Kench curing does have one key advantage, it does not require a watertight container to hold the fish during salting, and so can be done with the minimum of facilities. The provision of washable containers, such as concrete tubs with pluggable holes at the bottom, and the use of a wet salting technique appears to have many advantages and is to be encouraged (Cole and Greenwood-Barton, 1965; Waterman, 1976).

When brining, a saturated solution should be used to ensure that salting is as rapid as possible and uniform between batches. There are practical difficulties in ensuring that the brine remains saturated as salinometers calibrated for tropical temperatures would probably not be available to the fish curer. Clucas (1976) suggested that dropping a fresh potato in the brine provides a useful guide to preparing a concentrated (about 80 percent saturated) solution; if the potato floats the brine is sufficiently concentrated, and if it sinks more salt must be added. Brining does have the advantage that relatively impure salt could be used without causing a decrease in the sodium chloride level of the final product. The salt content of the final product can of course be regulated by altering the duration of brining.

In general increasing salt levels during poor drying weather up to the possible maximum (that is saturating) levels is advisable within the confines of what is acceptable to the consumer. Watanabe and Mensah (1976) observed that salt levels in salted dried fish varied from 13 percent (wet basis) in the dry season to 18 percent in the wet season in Ghana, so the benefits of heavier salting during adverse weather are sometimes appreciated by curers.

6.2.3 Improving the natural drying process

Basic methods: From chapter 2 it can be seen that the heat of the sun and the moisture removing effect of wind are the major factors which cause fish to dry. Raising fish off the ground on racks exposes them to more wind and increases the surface area of the fish in contact with the air. Hence raised racks will improve drying and are strongly recommended (Waterman, 1976). Sloping racks will allow excess surface moisture to drain away, preventing damp pockets forming in the gut and gill cavities of fish (Clucas, 1976).

At night the temperature falls appreciably in some areas leading to a rise in rh and possibly to dew formation. Areas of low daytime humidity are often subject to very wide temperature fluctuations so it is important to store drying (and dried) fish in a protected area overnight. Press piling (that is stacking moist fish under pressure) at night will aid drying by enabling water to diffuse to the surface of the fish for removal during the next drying period. Fish should, of course, be protected from rain either by removing them to a dry place or covering them with a waterproof (perhaps polythene) sheet. Very rapid initial drying leads to case-hardening and is undesirable, so under good drying conditions it may be preferable to dry fish in the shade at least initially.

Uses of solar driers: solar driers have several potentially attractive features for aiding processing in tropical areas. They have no energy cost and may provide a potential method for drying fish even when the rh is very high. Their construction can be very simple,

although relatively sophisticated designs have been suggested. Designs having no mechanical parts to break down have been used, and these would clearly be attractive for use in small-scale fish processing. It must be said, however, that the admittedly limited development work done so far on solar fish driers has yet to demonstrate consistent advantages over conventional sun drying in a commercial situation.

Doe and co-workers (Doe *et al.*, 1977; Doe, 1979, a) have pioneered the use of a simple tent of polythene sheeting supported on a bamboo frame (Figure 11). In Bangladesh improved drying times for fish were noted, as well as an inhibition of blow-fly larvae infestation due to the elevated temperatures. There were, however, considerable problems found with the design. Accurate temperature control was difficult, if not impossible, to achieve. Temperatures of over 60°C were reported by Doe (1979) which may have had adverse effects on the nutritional quality of the fish. Other practical problems reported by Doe *et al.* (1977) were that the polythene became brittle after 2 months in the sun, and during high winds gaps in the sheeting prevented temperatures rising above 37°C, which was insufficient to prevent flies attacking the fish.

Meynell (1978) tried three types of solar dryers in Malawi during wet and dry seasons. A brick and glass solar kiln, a solar tent similar to that of Doe *et al.* (1977), and an insulated solar box were all put to practical trials. During the dry season there was little difficulty in using the conventional sun drying process, and only minor improvements were observed. Poulter (1980) reported that solar tents led to marginal improvements when used in Sri Lanka, reducing drying times from 5 to 4 days, and Richards (undated) working in Papua New Guinea reduced drying times from 5 to 6 days to 3 to 4 days using a similar design of solar tent. The increased rate of drying appears to be due almost entirely to speeding the final stages of the drying process (Doe *et al.*, 1977; Ismail, 1980), a period when blow-fly attack will be minimal.

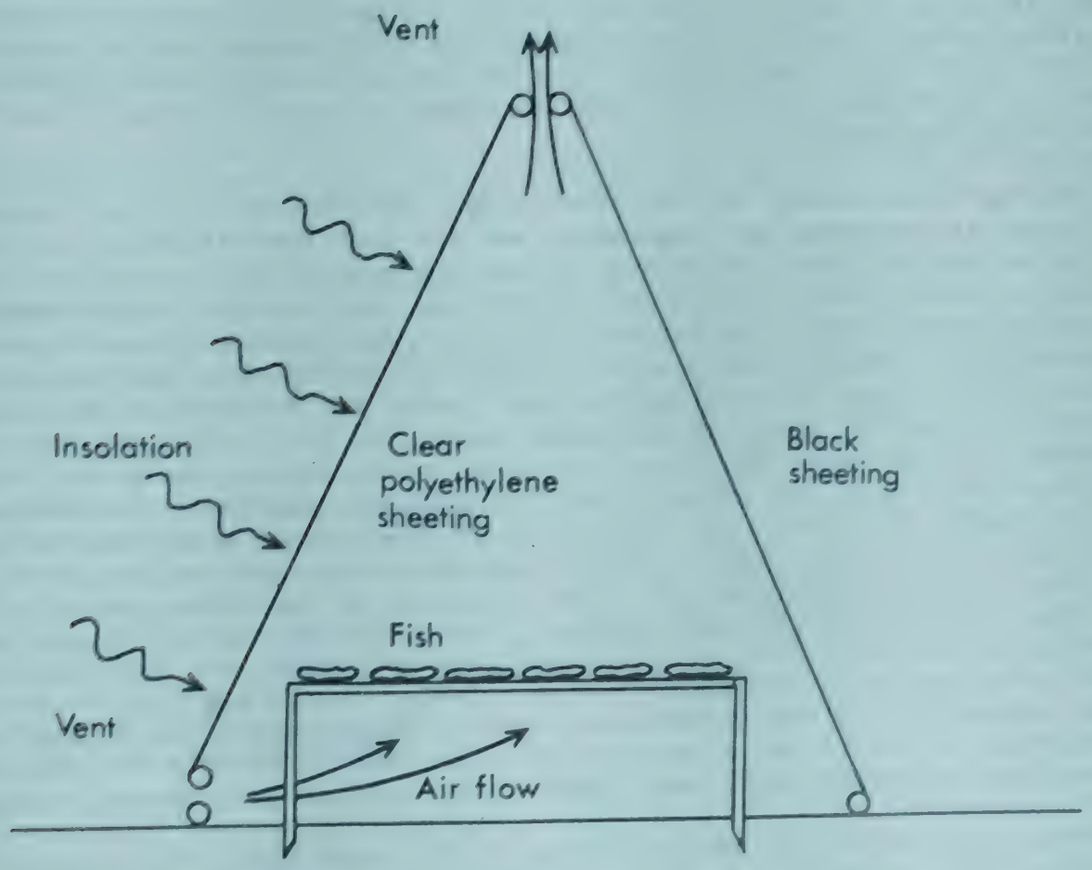


Figure 11 - Schematic drawing of polythene tent drier

Perhaps more significantly Meynell (1978) found the design unsatisfactory during the wet season. Lack of sunshine led to low temperatures inside the dryers, which in turn led to low air flow rates and slow drying. Ismail (1980) expressed doubts as to whether solar driers would be satisfactory during wet weather as the process was weather-dependent, and he suggested that alternative fuels such as agricultural waste would have to be used.

Chakraborty (1978) has described a fish drier which used a black painted galvanized iron heat collector coupled to a separate fish holding section. An electrically powered fan was used to force the heated air from the heat collector and over the drying fish. Temperatures of 45°C (30-32°C ambient) were achieved. The major problem with this approach is that it is energy-consuming and requires relatively expensive equipment, and is only likely to be of possible use in larger-scale processing operations. It may, however, be possible to control air flow and temperature sufficiently for such a drier to be used for the initial drying of fish.

Some considerations on the suitability of solar driers for fish drying: Solar driers of various designs have been successfully used in drying fruit, vegetables, rice and cereal grains (review by Löf, 1962). It must be noted that the generally low permeability of the surface layers of fruit and vegetables, the low initial moisture contents of rice and cereals (often in the order of 18-20 percent), and the particularly high susceptibility of moist fish to blow-fly attack and spoilage means that driers proven to be useful for some purposes are not necessarily suitable for fish drying.

It was noted in chapter 2 that the initial rate limiting process for fish drying was the rate at which moisture evaporated from it, while the rate of diffusion of water through the flesh was important at later stages (Waterman, 1976). Optimal drying conditions have been established (see later in this chapter) which have shown that initially high temperatures cannot be used, so that air flow is of major importance. Natural convection cannot provide high enough air flows at the temperatures required, and hence initial drying in the simple dryer is no faster than that of conventional drying (Doe *et al.*, 1977; Ismail,1980). Without the use of a fan it is difficult to see how solar driers can out-perform the natural drying process during the all-important initial drying phase when blow-fly attack can be a particular problem. When still, very humid conditions prevail, natural drying may be so impaired that solar driers may be an improvement, but these must be shown to be sufficient to justify the cost and effort of using the drier.

Alternative uses of solar energy in fish processing: For the later drying stages, or for heating dried fish, the problems of temperature and air flow control are of relatively minor importance as neither is likely to greatly affect the quality of the product in most practical situations. Szabo (1968) and FAO/PNUD (1970) had used a solar box to heat dried fish to deinfest it, and Kent (1980) also suggested that this approach may be useful where infestation by *Dermestes* spp. is a problem (see chapter 5). FAO/PNUD (1970) were able to obtain temperatures of 70°C or over for at least 10 h/day when a small solar box was used in Mali. Diouf (1980) used enclosed solar tents made of wood and polythene sheets for the storage of dried fish at elevated temperatures. It was found that in an enclosed system the hot moist air formed during the day had to be expelled before the cooler night temperatures experienced in Senegal led to condensation forming inside the tent. The need to screen the storage area from the soil has also been noted (Diouf, 1980; Kent, 1980). Proper designs and procedures for ventilating such fish stores have yet to be developed, but they do appear to have some potential in inhibiting both insect infestation and mould attack. The effect on the nutritional value of elevated temperatures on the dried fish will have to be investigated more thoroughly to determine what treatments are possible, but there is some evidence that dried fish protein is relatively stable (see chapter 3). Diouf (1980) noted that although superficially unaffected by these elevated temperatures, there was a tendency for some fish to crumble and the products also had less odour than untreated ones, both factors which may affect consumer acceptability.

In conclusion it can be said that while the use of high temperature disinfestation and solar drier-like dried fish stores may be of considerable value, especially in countering *Dermestes* spp. infestation, there are potential problems which require further study before the methods can be advocated with total confidence. It is unclear whether solar driers can effectively prevent blow-flies infesting unsalted fish.

6.2.4 The use of artificial driers

Optimal drying conditions: Specialized drying processes such as freeze-drying are generally considered to be unsuitable for the situation found in developing countries (Rogers, 1975) and often give a product different from the traditional dried ones, therefore only mechanical driers will be considered in this section. Fish can be dried using external energy consuming heat inputs and air circulating systems. Conditions can be controlled to give good quality insect-free products even under the most adverse weather conditions. Waterman (1976) recommended a temperature of 27°C, 45-55 percent rh and 60-120 m/min air flow for the optimum drying of fish from temperate waters, but noted that higher temperatures have been successfully used for tropical species. Optimal conditions of 45-50°C, 60-65 percent rh and 120 m/min air flow were found by Chakraborty (1978) using Indian fish species. An optimal drying temperature, not high enough to cook the fish, of 45-50°C for tropical species seems to have received general acceptance (Balachandran, 1969; Prabhu *et al.*, 1963; Disney, 1974), and an rh of 50 percent (Suryanarayana Rao and Khabade, 1968), or possibly up to 65 percent (Chakraborty, 1978), probably depending on air flow, appears to give the fastest drying rates and prevent case-hardening.

In general, therefore, the optimal drying conditions for tropical fish species do appear to be quite well established. It is possible, however, that some species may be less stable at these elevated temperatures than others, Suryanarayana Rao and Khabade (1968), for example, found that salted Indian mackerel started to cook at 50°C.

Feasibility of using artificial driers: Disney (1974) using a diesel oil burning heater, showed that artificial drying was both technically and commercially feasible during the wet season in Malawi and year-round uninterrupted production was clearly advantageous. Sun drying was, however, inevitably cheaper during the dry season and so was more profitable than artificial drying. Chakraborty (1978), using electrically or steam-heated tunnel driers, concluded that artificial drying added relatively little to the cost of dried fish production and may be viable for sufficiently large operations if powere was available. The work of Disney (1974) does suggest, however, that this increased cost of production is not likely to be reclaimed by higher prices. Shahidullah (1978) noted that in Bangladesh a conventional mechanical drier has been introduced and run commercially, but was abandoned as the operation proved uneconomic. Therefore there must be considerable doubt as to whether artificial drying is commercially viable as an alternative to traditional drying techniques in developing countries.

More technically sophisticated artificial drying equipment has been developed. Increasing the temperature of the fish as the moisture level falls to accelerate the process greatly increases the throughput of the fish (Anon., 1963). In Portugal, mechanical driers working on the heat pump principle have proved economic (Anon., 1974). The process consists of a closed circulating air system and a heat pump, similar to a normal refrigeration unit. Air is drawn over the fish and into a condenser which removes moisture from it, the condenser being cooled by the cool side of the heat pump. The air is then warmed by the warm side of the pump and recycled over the fish. Although the improved systems may be more fuel-efficient and technically superior, their increased sophistication may lead to higher installation and maintenance costs which can make them unsuitable for developing countries. Another major problem with any artificial drier is the scattered nature of fish landings and present traditional processing. Larger, more centralized landing sites may be required to supply sufficient fish to make it economically attractive.

6.2.5 Improving the smoking process

Design of some improved smoking kilns: Smoking kilns should be as fuel-efficient as practically possible, and should be able to operate at controlled temperatures to prevent excessive textural and nutritional damage to the fish (chapter 3). Traditional smoking processes are often uncontrolled and haphazard, as well as being very fuel-inefficient even under circumstances when fuel is expensive (Spurgeon, 1974). Enclosed fire-boxes with

adjustable ventilation holes are more fuel-efficient and controllable than open pit-type kilns, while more uniform smoking and better temperature control can be achieved by separating the fire from the fish and by using a baffle as a smoke-spreader. Improved kilns need not be technically complicated and can process a higher throughput of fish than many traditional types.

The designs shown in Figures 12 and 13 are broadly similar in that they are of permanent construction, having an enclosed fire-box directly or indirectly under an area where the fish are held on mesh trays which allow the smoke through. These kilns are more expensive to construct than the very simple traditional types which might limit their suitability in some areas. The mud and pole smoker (see Figure 14) developed for use in Zambia may be more appropriate under some circumstances. It consists of an oil drum fire-box linked to a fish holding smoke chamber constructed of wooden supports, reed and mud walls and a thatched roof. It has the advantage of relatively cheap construction if the materials are available locally. Although Cabrita and Watanabe (1971) have described a plant which could process up to 2 t of fish per day, smaller ones processing about 100 kg of fish per day have also been described (Watanabe, 1975). The increased cost and capacity of the improved kilns may require more centralized processing than is presently found, and may be a constraint on their introduction.

Berg (1968) and FAO (1970) described more sophisticated controlled smokehouse designs which are used for making products popular in developed countries. These rely on fans to move the smoke over the fish rather than relying purely on natural convection. The relatively high installation, running and maintenance costs of these types means that they cannot be regarded as suitable for most tropical countries.

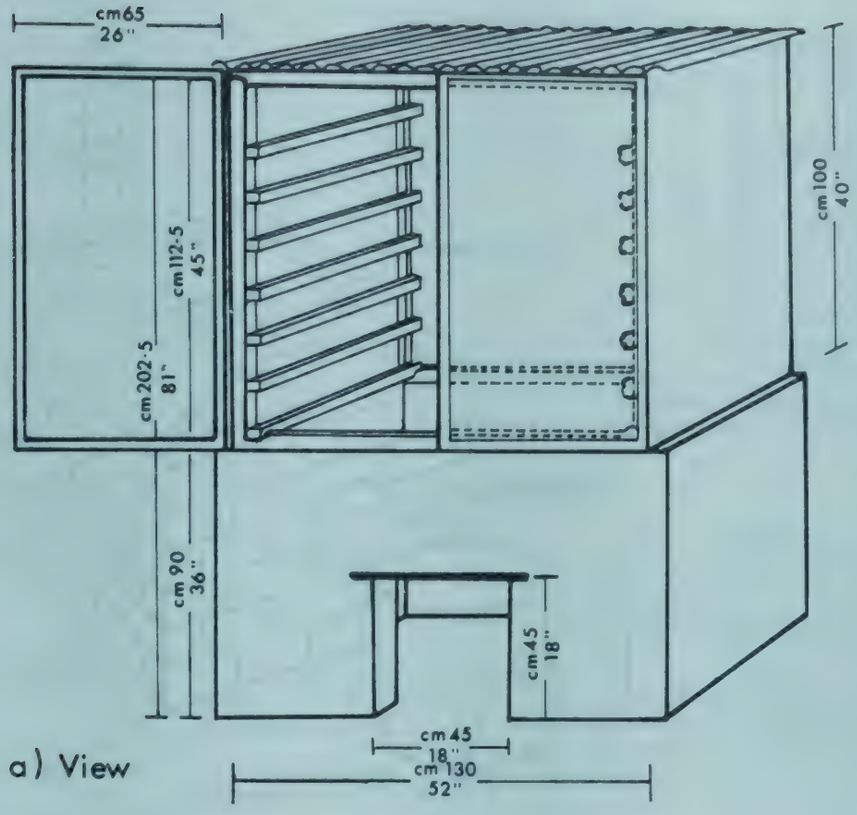
Performance of improved kilns: Using a kiln of the design similar to that shown in Figure 12, Rogers (1970) demonstrated some marked improvements in processing compared with the traditional fire pit and table kilns found in Uganda. Processing times were reduced from 3 to 1-2 days while also reducing the final moisture contents of the products. The improved kiln was over 7 times more fuel-efficient than traditional designs (2.1 kg firewood per kg fish processed for traditional pit and table, 0.27 kg firewood per kg fish processed by the Rogers kiln).

While the improved kilns should prevent charring of the fish which can occur in the traditional kilns, the problem of temperature control should be given more attention than has previously been the case. Watanabe and Cabrita (1971) suggested using a remote fire-box coupled to a fish holding section by a 1-2 m flue pipe. Although having the fish directly over the fire ensures that higher temperatures can be reached (FAO, 1970), for "warm" smoking at lower temperatures the Watanabe and Cabrita (1971) design (Figure 13) has advantages.

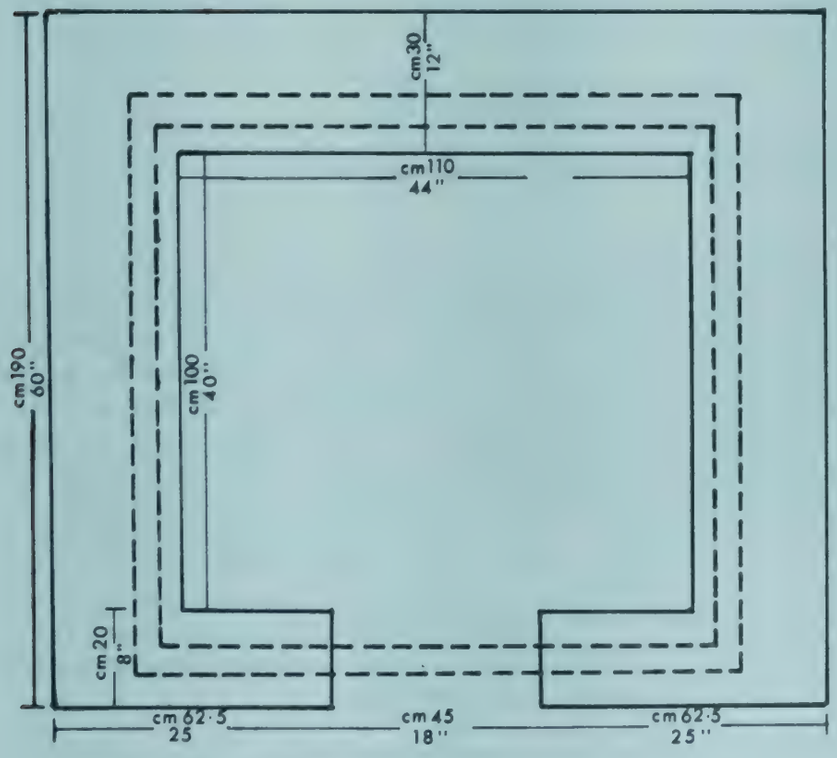
For a particular design of kiln, the temperature of the fish is determined by the strength of the fire. With an enclosed fire-box adjustable ventilation holes can be used to control this, and the design of the kiln coupled with the skill of the operator will determine the temperatures at which smoking is performed. Watanabe (1975) found that the separate fire-box kiln (Figure 13) could be used at temperatures between 40-130^{o}C, although no indication was given as to the degree of temperature fluctuations during normal operation.

Desirable smoking temperatures: The work of Hoffman *et al.* (1977) had suggested better temperature control is required than that which is found in traditional processing procedures. Improved kilns will give the potential for improvements but in themselves they do not ensure that smoked fish does not suffer appreciable nutritional damage during processing. Better processing techniques where excessive temperatures are avoided must also be introduced. Perhaps just as important, the smoking procedures must be re-examined with regard to the problem of fragmentation. Mills (1979) suggested that light brining (2-3 percent salt in final product) may help, although this has yet to be confirmed (Moes, 1980; FAO, 1980). A rather more basic re-examination of the process must also be suggested.

Assuming that the required product needs to have a long storage life then it must be thoroughly dried during processing (final moisture content of 8-12 percent and yields of



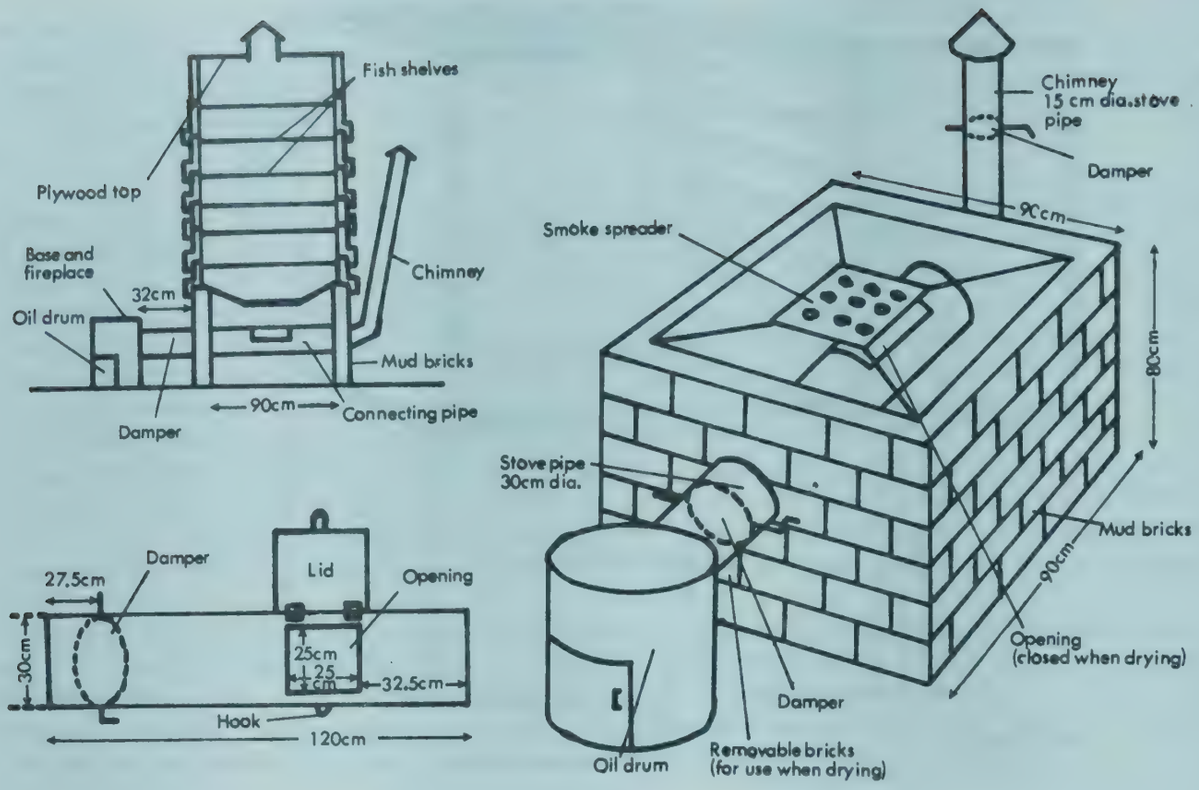
a) View



b) Fire – box, ground plan

Source: FAO 1971a

Figure 12 - Simple version of Altona-type oven



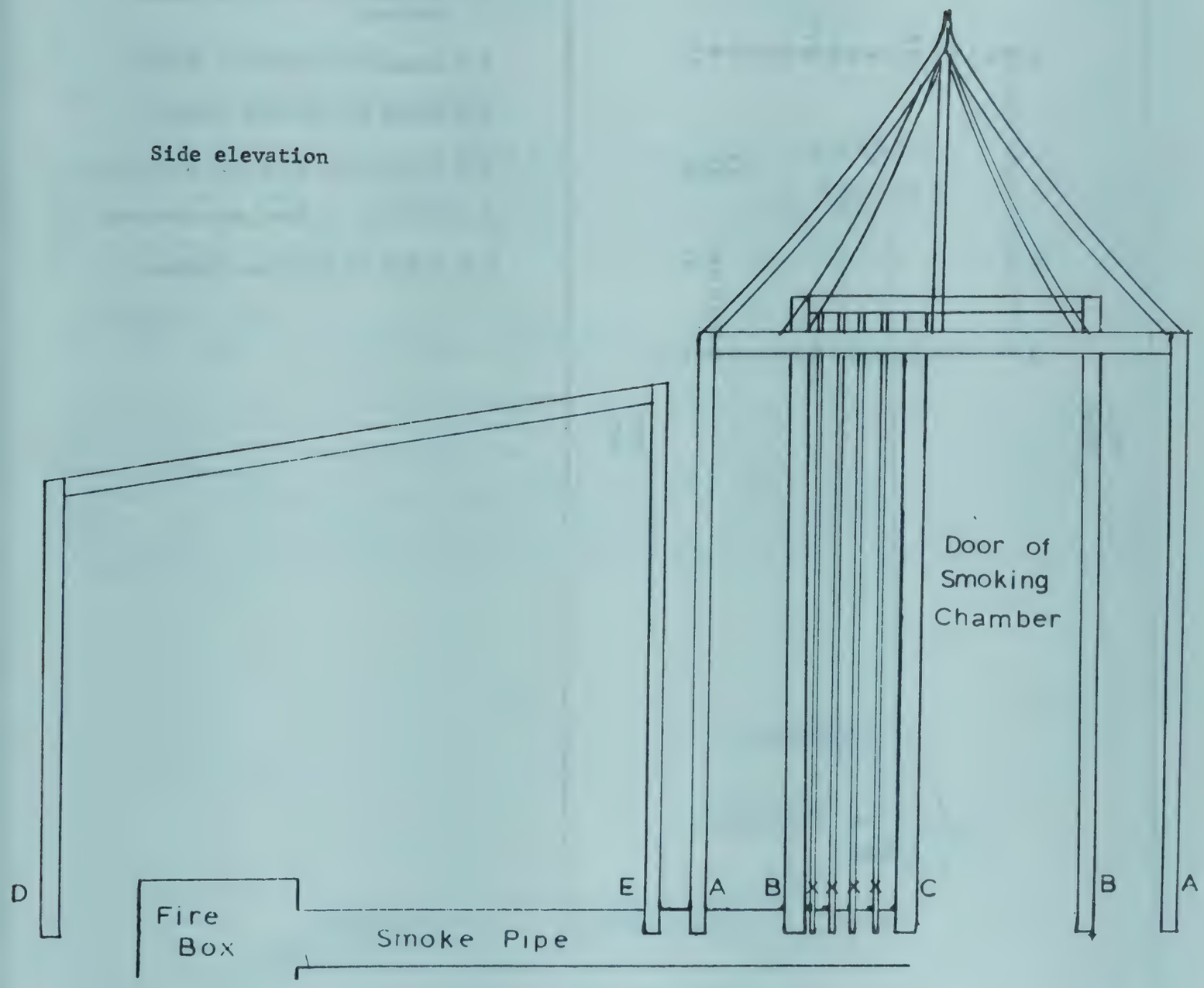
Source: Watanabe, 1975

Figure 13 - Fish smoker and drier

22-30 percent of the original fish weight are suggested by FAO (1970)). If this product is cooked then it will almost certainly be susceptible to losses due to fragmentation. The temperatures traditionally used are really more relevant to a hot smoked relatively moist product with a limited shelf life. For a well preserved dried product it must be suggested that the temperatures should be the same as those used for artificial drying for exactly the same considerations if a directly comparable product which will not fragment is to be produced. Watanabe and Cabrita (1971) have described a method whereby fish are brined so as to give 8-10 percent salt in a final product, sun dried so that the fish weight falls to 75-80 percent of the original dressed weight and smoked at 45-60°C. Further sun drying can be used to obtain the suitable final moisture content. They noted that smoking at 90-110°C produced a very brittle product, and that smoking without allowing sufficient time after salting caused brittleness, presumably because the moisture content of the fish was too high. While noting that excessive initial sun drying will prevent good smoke penetration, the products prepared by Watanabe and Cabrita (1971) were acceptable in Zambia.

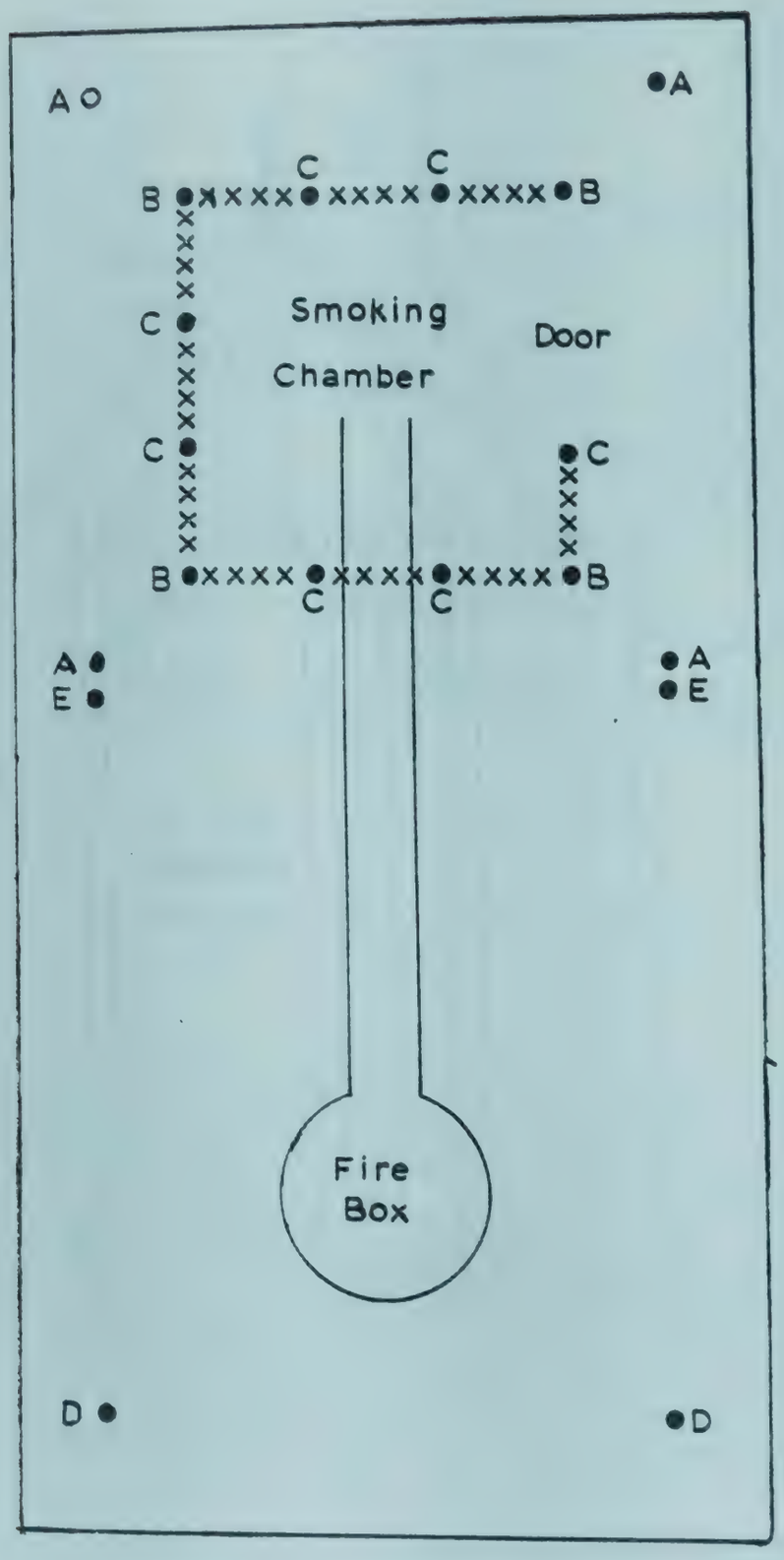
It is suggested that the lower end of the temperature range (say 45°-50°C) might be more suitable (at least initially) perhaps rising to higher levels as smoking continues. This approach may be effective in reducing fragmentation losses and should be investigated further, although care must be taken to ensure that the temperatures used are sufficiently high to inhibit blow-fly infestation and lead to adequate drying.

The re-smoking of smoked products: Periodic re-smoking of fish which has been previously smoked may be used to re-dry the fish and also as a method of insect disinfestation. Osuji (1973) found that in the Kainji Lake area of Nigeria it was common practice to keep smoked fish in a chamber over a smoking kiln so that it was continuously re-smoked. The temperatures



Source: Clucas, 1976

Figure 14 - Part I - Mud and pole smoker



KEY

A = Corners of Smoking Chamber Shelter

B = Corners of Smoking Chamber

C = Sides of Smoking Chamber

D = Corners of Fire Box Shelter

E = Corners of Fire Box Shelter

x = Sides of Smoking Chamber

Figure 14 - Part II - Plan for main support poles

of 38-72°C found were sufficient to prevent insect infestation. FAO (1971a) suggested a design of partially open box (Figure 15) which would enable periodic re-smoking without having to unpack and re-pack the fish. This design may be particularly useful in controlling insect infestation by heat treatment, but may lead to extremely high losses due to fragmentation unless care is taken to process the fish correctly initially.

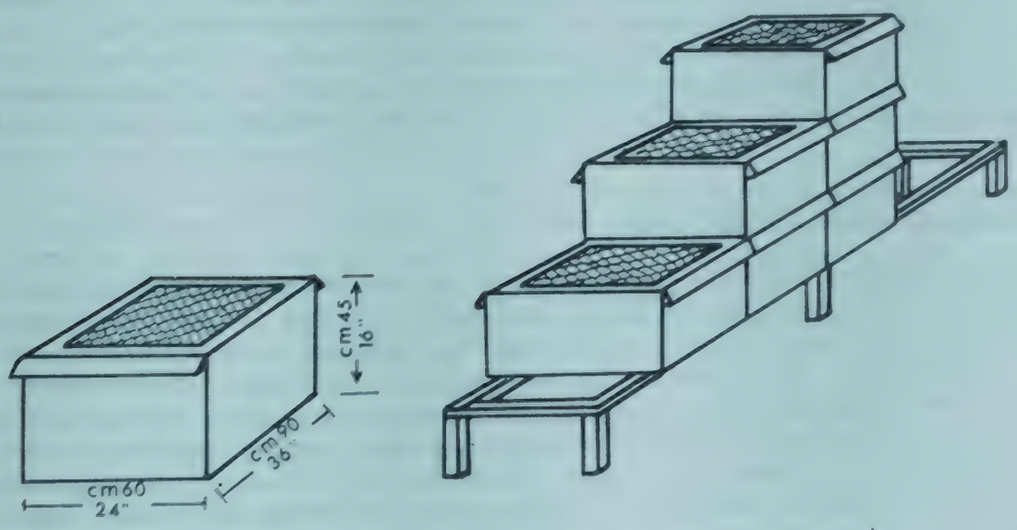
6.3 Extension Requirements

6.3.1 Basic education and training

In the cured fish industry there are many basic educational problems such as the lack of awareness of the importance of hygiene and the acceptance of losses of fish as inevitable. The points made earlier regarding very simple measures which could lead to general improvements, as well as the ones to counter particular problems when observed, should feature in any extension work programme. It is perhaps worthwhile quoting Osuji (1973) on the subject of insect infestation of dried fish:

> "by both trader and consumer the presence of insects in dried fish is presumed to be normal, and any attempt at control seems obviously irrelevant".

Clearly a major extension requirement is to demonstrate that better cured fish products can be made and that losses can be substantially reduced by techniques appropriate to the practical limitations of the particular situation. The more careful and thorough use of existing techniques such as heavier salting and longer drying times may be appropriate in many cases. More sophisticated improvements may also be appropriate under certain circumstances. Input from experts would be required to install equipment and to train local personnel, exact details of such a programme depending entirely upon the proposed scheme which is being introduced.



a) - Wooden storage box

b) - Rack for re-drying boxed smoke-dried fish

Source: FAO, 1971a

Figure 15 - Marketing boxes for smoke-dried products

6.3.2 Extension and research work

An extension programme must be well organized and its staff sufficiently trained for it to be effective. There must be adequate cooperation and communication between all the workers involved in fisheries so that problems are identified in the field by extension workers, the problems evaluated and solutions found by scientists, and the improvements introduced by the extension programme. Cole (1977) has reviewed the role of extension work in small-scale fisheries development in some detail, and stressed that extension work and research and development overlap when applied to small-scale fisheries. Improvements will not be implemented unless they are shown to be worthwhile to the artisanal fisherman and fish processor, and establishing improved methods is the object of research and development in the later stages of a project. Suggested improvements, whether they are very simple or relatively sophisticated, must be shown to be useful and relevant to the particular situation. If this cannot be done then suggestions will almost certainly be ignored by the fishermen and processors however good they are.

Hence scientists will not be effective in introducing the improvements developed without an extension programme, while extension workers will not be effective without the help of scientists in developing the required improved techniques.

6.3.3 Introduction of quality control

As the agents which cause loss of product quality also generally cause loss of nutrients, quality control will have a role in loss reduction. At present quality control is most noticeable for its absence in an organized or consistent form. Unless the trader pays more for better products from his suppliers, and eventually from the processors, there is no incentive for a processor to make better products. If they are bought by weight, as is often the case, there may even be an incentive for preparing damp products which may suffer from considerable losses during distribution. If the distribution system is such that products become mixed and quality deteriorates, improved processing alone may have little effect on the quality of products at the market place and only have a marginal effect on losses. There is, therefore, a need to educate the consumer to encourage a greater discrimination for better products, and more formal quality grading by trained inspectors would help. Improvements in distribution are required to maintain the quality of the product. In the final analysis it is the consumer who decides what a product is worth, and a basic problem may be that all too often only poor quality products are available and so the consumer is only familiar with these.

6.3.4 Centralization of fish processing

Much traditional fish processing is performed at scattered sites, but improvements which require investment or trained personnel will inevitably favour larger-scale operations. There may be problems encountered when trying to change the present system of the dried fish trade where it favours high levels of losses. The extension worker must therefore be aware that the existing system has evolved over many years in a way which has been determined by techniques in general use, so that changes in techniques may obviate changes in the system. The use of modern roads and lorries for distribution has, for example, already led to centralized collection and distribution points in some areas. These may be areas where new techniques can be introduced without requiring additional changes in the present organization of the trade, as these will already have occurred.

Processing may present more serious problems. Consider the introduction of an improved smoking kiln to replace say three small traditional kilns. Assuming the kiln capacity is not too large for the fish supply available, the problem is to persuade three processors, probably organized as family concerns perhaps catching all their own fish, to cooperate in the operation of a single kiln. Obviously very basic social changes would have to be made if the venture is to be a success. While a measure of centralization may be appropriate, a very major advantage of traditional processing is that it can be done on a small-scale and there is a large degree of flexibility possible in the scale of production. It would be a mistake

to encourage larger-scale operations for their own sake, rather they should be seen as a possible side-effect of improved techniques and development, and one which can have disadvantages.

New techniques and restructuring the industry, although beneficial to many if the levels of cured fish available are increased, may adversely affect a large number of people involved in the industry itself. Centralization will inevitably decrease the numbers of traders and middlemen as the scale of individual business increases. It must be born in mind that the traditional industry provides employment to large numbers of people whose livelihood may be threatened by changes which would be resisted as a result. Changes should be socially acceptable as well as generally beneficial.

7. SUPPLEMENTARY PEST CONTROL TREATMENT

7.1 Uses of Insecticides

Where insect pests cannot be prevented from infesting dried fish by other means it may be necessary to resort to the use of insecticidal chemicals. These could be applied directly to the fish as residual contact insecticides, or as fumigants which act in the gaseous phase and provide no residual protection. Insecticides may also be used indirectly on the surfaces of containers or in processing and storage areas.

7.2 Use of Contact Insecticides

7.2.1 Recommended residue levels

Insecticides to be used for direct application to dried fish must be sufficiently toxic to the target insect pests whilst not leaving residues harmful to the consumer. Few insecticides are able to control the major insect pests of dried fish at application rates low enough to ensure low residues.

The guidelines generally used to determine whether residue levels are safe are the Maximum Residue Limits (MRL) recommended by the FAO/WHO Joint Meeting for Pesticide Residues (JMPR) and the Codex Alimentarius Commission. The only currently recommended MRLs on fish are pyrethrins 3 mg/kg and piperonyl butoxide 20 mg/kg, recommendations which are the same as the pyrethrum residue limits for cereals and probably have the same origin because there has been very little published work on the residues resulting from pyrethrum treatment of fish. The treatment of fish with malathion is known to result in very high residues (Green, 1967; Proctor, 1972) and this explains the reluctance to use insecticides other than the synergised pyrethrins. The residues of pyrethrum and other insecticides resulting from the dipping of wet and dry fish has shown that adequate control is not possible unless treatments are used from which residues of 10 mg/kg or possibly 20 mg/kg may occur (Tropical Products Institute, unpublished results). There is, therefore, a need for assessment of the permissible MRLs to be carried out by the JMPR. Since dried fish usually constitutes a relatively small proportion of the human diet compared to cereals, it may be possible to set MRLs at a higher level for fish than for cereals without serious danger that the acceptable daily intake for the insecticide would be approached. The insecticide residues are difficult to analyze and require a relatively high level of laboratory facilities. The determination of residues under field conditions is not possible. This is an inevitable experimental problem.

7.2.2 Use of insecticides to control blow-flies

Insecticides have been used to prevent or reduce blow-fly damage in drying fish by preventing oviposition by adult blow-flies and controlling developing larvae. The problem is most acute when initial drying is slow (see chapter 3), and is, therefore, one of achieving sufficiently rapid drying or adequate protection during the drying period. The recommended insecticidal treatment (McLellan, 1963; Green, 1967; Morris and Andrews, 1968) is to dip in a solution of 0.125 percent pyrethrins, 0.250 percent piperonyl butoxide. There has been little published work on the residues resulting from these dipping treatments, partly due to

the difficulty of the analysis and partly to the assumption that pyrethrins are safe and would be broken down in the light. Moreover, the levels found are probably open to question due to the inadequacy of the analytical methods such as bioassay with mosquito larvae. Malathion residues were found to be high (Table 11, Part I) at the levels needed, and this prevented the recommendation of malathion for the dipping of fresh fish.

Diouf (1980) used synergised pyrethrin treatment to protect several species of marine fish. 0.125 and 0.25 percent pyrethrins (1.25 and 2.5 percent piperonyl butoxide) were better than 0.0625 percent pyrethrins and gave very good protection for up to 120 days. The residues of pyrethrins varied from 1 to 27 mg/kg but were generally below 3 mg/kg, but the very high residues of piperonyl butoxide (50-430 mg/kg) were all in excess of the MRL (20 mg/kg). The high ratio of piperonyl butoxide to pyrethrins used (10:1) is not generally favoured because of these high residues.

More comprehensive pyrethrin residue determinations on dipped fresh fish from Malawi were carried out by TPI in 1976 to 1979. The recommended 0.125% pyrethrins, 0.250% piperonyl butoxide dip was shown to result in residues of 12 mg/kg and 70 mg/kg respectively. Mixed species (locally called Chisawasawa) were used, and because it was dried intact the fish gut tended to take in the dip. This probably contributed to the high residue because the internally held insecticide would be less exposed to light. To reduce the residue levels, lower concentration dips were used and ratios of pyrethrins to piperonyl butoxide of 1:2, 1:1 and 1:0 were compared. Total removal of synergist greatly reduced the effectiveness, and the 1:1 ratio was certainly not as good as the 1:2. The reduced concentration of pyrethrin also had greatly reduced effectiveness. A dip containing 0.033 percent pyrethrins, 0.066 percent piperonyl butoxide was quite inadequate in its protective effect. Average residue levels from dipping at this concentration were 1.7 ppm pyrethrins and 21 ppm piperonyl butoxide. Only one sample exceeded the 3 ppm maximum permitted residue limit for pyrethrins but four samples exceeded the 20 ppm limit for piperonyl butoxide. It is likely that more samples would have exceeded the residue limits had the concentrate used for the dipping solution been up to nominal strength since it was later found that the concentrate had only 70 percent of the nominal strength for pyrethrins and piperonyl butoxide. The residue levels from other fish dipping experiments are given in Table 11, Part II.

There were also other problems with the dipping procedure. It was found that the dip was rapidly depleted and therefore not economic. An alternative technique was to douse the fish with insecticide solution which was then recirculated. This proved to be much less effective biologically, it being difficult to completely treat all fish, whilst the solution rapidly became polluted and the bacterial counts of fish treated later were noticeably raised.

Even without the residue situation the cost of 0.125 percent pyrethrum dips might be much too high and the natural insecticide is difficult to obtain. One of the main advantages of synergised pyrethrum was the repellency which prevented the blow-fly from landing and contaminating the fish. An alternative insecticide, although being more toxic to insects, might be less desirable without this repellent effect. Other trials comparing alternative insecticides such as pyrimiphos methyl and permethrin with pyrethrins are being undertaken by TPI. Whilst there is a good case for raising the MRL, it is likely that in the long term insecticide treatment will not be favoured as a useful preventative measure against blow-fly due to the problems of high residue levels.

7.2.3 Use of insecticides on dried fish

Most of the work reported on the use of insecticides on dried fish has been for the control of *Dermestes* spp. *Necrobia rufipes* is also an important pest of dried fish (see chapter 5) but little has been published on its control with contact insecticides. The standard recommendation for the protection of dried fish, resulting from the work of McLellan (1964), Green (1967) and Proctor (1972), is dipping in an aqueous solution containing 0.018 percent pyrethrins and 0.036 percent piperonyl butoxide. There has been very little reliable analysis of pyrethrin and piperonyl butoxide residues in dried fish due to the difficulty of the

Table 11

Insecticide residues resulting from dipping fresh fish
Part I - Treatment with malathion

Strength of dip (%)	Residues (mg/kg)			
	Period between treatment and analysis (weeks)			
	0	4	6	12
0.125 (a)		27	14	
0.500		64	34	
0.500	327			
0.72 (b)				44

Sources: (a) Green (1967)
(b) Somme and Gjessing (1963)

Part II - Treatment with pyrethrins and/or piperonyl butoxide

Type and strength of dip (%)		Residues (mg/kg) analysed 1 week after treatment
Pyrethrins	Piperonyl Butoxide	
0.125	0.250 (c)	1.2
0.250	0.500	5.8
0.0125	- (d)	1.3
0.025	-	4.3
0.050	-	7.8
0.100	-	9.2
0.200	-	29
0.300	-	37
-	0.125 (d)	71
-	0.25	72
-	0.50	96
-	1.0	262
-	2.0	590

Sources: (c) Morris and Andrews (1968)
(d) TPI (unpublished results)

analysis. Somme and Gjessing (1963), stated that cod and saithe dipped in a 0.2 percent insecticide solution was found to contain less than 1 ppm of pyrethrins after 5 months storage, but it is likely that the levels reported are not accurate due to the unreliable analytical methods then available.

Though effective in controlling insect pests, synergised pyrethrins are expensive and difficult to obtain. It must also be assumed in comparison with other insecticides (see below) that appreciable residues will result from the dipping treatment. For example Green (1967) found that the minimum effective rates necessary left unacceptably high residues.

Green (1967) also concluded that treatment by dipping and soaking in 0.0625 percent malathion solution left high residues (up to 27 mg/kg) even after 4 weeks storage for all marine species of fish tested, except shark on which insecticide breakdown was rapid. Proctor (1972) reported residues of up to 28 ppm for *Tilapia* spp. dipped in a 0.0625 percent malathion solution and up to 43 ppm using a 0.125 percent solution, both analyses being undertaken after an 8 week storage period. These results are given in greater detail in Table 12, Part I.

Guillon (1976) reported effective control of *Dermestes* spp. in Mali using dipping in aqueous solutions of tetrachlorvinphos. The best results were obtained using a 0.1125 percent dip. Three concentrations of tetrachlorvinphos were tested, the fish being soaked in the aqueous insecticide solutions for approximately one minute. The residue levels found were as shown in Table 12, Part II. The results seem rather low compared to the levels given in Table 12, Part III, which were averaged from many analyses of organophosphorus residues in dried fish. Guggenheim (1980) states that 602-605 bags of tetrachlorvinphos were sold in 5 g packages in Mali in 1979 by the "Opération Pêche" project, although no internationally accepted maximum residue limit has been set for tetrachlorvinphos in fish or indeed any food grains.

With some new synthetic insecticides relatively dilute dipping solutions are effective in controlling *D. maculatus* (TPI, unpublished data). The most effective insecticides in the trials were pirimiphos-methyl and chlorpyrifos-methyl, both organophosphorus compounds of moderate mammalian toxicity. The synthetic pyrethroid, permethrin, was moderately effective when used on dried *Clarias* spp., 0.00625 percent solutions of both pirimphos-methyl and chlorpyrifos-methyl giving reasonably good protection to dried *Clarias* spp. against adults and larvae of *D. maculatus*, and residues in the fish being in the order of 5-10 mg/kg. Better control was achieved with 0.0125 percent insecticide dips, and the residues were in the order of 10-15 mg/kg from this concentration. Permethrin applied as a 0.0125 percent dip gave good control of *D. maculatus* larvae but was much less effective against the adult insect.

In northern Nigeria pieces of smoke dried fish of the species *Tilapia, Heterotis, Gymnarchus* and *Clarias* were dipped into aqueous solutions containing 0.0125 percent chlorpyrifos-methyl, pirimphos-methyl or permethrin. Good control of *D. maculatus* was achieved and adequate protection against this pest was conferred by all three insecticides tested during the three weeks in which the treated fish was exposed to the natural insect infestation present in the storage area (Taylor, 1981).

7.2.4 Hazards of using contact insecticides

In many countries the use of insecticidal sprays or dips to protect dried fish is not considered favourably. This may be due to genuine lack of information regarding potential benefits that can be derived from such treatments but it may also be due to the fear of toxic residues. These might occur especially if insecticides are misused, and there is no doubt that many potentially hazardous treatments are in use. It has been reported by Rodrigues and Dos Santos (undated) that malathion, BHC and DDT are used to protect salted fish from flies either by dusting onto the fish by mixing with the salt, one soup spoonful to each sack of salt, even though adequately salted fish is resistant to fly infestation (see chapter 3). Guggenheim (1980) states that gammalin 20 (a concentrated gamma BHC formulation used to treat field crops such as cocoa) is used to protect fish, and merchants toss handfulls of BHC onto fish cartons and floors. Taylor (unpublished observations) reports

Table 12

Insecticide residues resulting from dipping dried fish
Part I - Treatment with malathion

Strength of dip (%)	Residues (mg/kg		
	Period between treatment and analysis (weeks)		
	2	4	8
0.0625 (a)	53	33	27
0.125	88	60	40
0.0625 (b)		5-13	
0.125		22-27	
0.500		32-64	

Sources: (a) Proctor (1972)
(b) Green (1967)

Part II - Treatment with tetrachlorvinphos

Strength of dip (%)	Residues (mg/kg) after 11 days	Residues (mg/kg) after 194-208 days
0.1125	-	0.32
0.0750	7.6	0.12
0.0375	4.8	0.70

Source: Guillon (1976)

Part III - Treatment with organophosphorus insecticides (chlorpyrifos-methyl and pirimiphos-methyl)

Strength of dip (%)	Residues (mg/kg) after 1 week (mean results for several treatments)
0.00625	5-10
0.01250	10-15
0.050	60

Source: TPI (provisional results)

that household aerosols containing BHC or dichlorvos are used to control insects in fish. Dried fish has been observed being packed in matting treated with malagrain (malathion presumably) (Guggenheim, 1980).

More research is necessary to identify suitable insecticides, and equally important is collection of data about residues in treated fish in relation to the consumer. The rate of disappearance of residues during storage must be assessed together with the effect of cooking since most, if not all, dried fish is cooked prior to consumption. Once there is more information available and potential users are made aware of the advantages a more general acceptance of the use of contact insecticides to protect dried fish may develop.

At the same time the hazards associated with insecticides should not be overlooked. Users should be given information on the way to use safer and more effective insecticides and not to use formulations such as gammalin 20 which are marketed for entirely different purposes.

7.3 Indirect Use of Insecticides on Surfaces

Control of insect pests inhabiting areas in which dried fish is stored and handled may be achieved using an insecticide spray. The aim is to produce a persistent insecticide deposit on all surfaces where insects crawl. Best results are likely to be achieved with this method when it is used in permanent storage sheds or handling areas in markets. These may be rare or non-existent in some rural locations where fish is processed and stored and it is unlikely that insecticidal spraying where no permanent structures exist will be effective. Because of the possibility that fish may pick up chemical residues when it is stored or handled in areas or buildings which are sprayed with insecticides, only those compounds recommended for use in food storage practice should be employed. Pirimiphos-methyl and chlorpyrifos-methyl might be acceptable as fabric sprays where dried fish is handled or stored. An application rate of 0.5-1.0 g/m^2 of insecticide may be effective.

Treatment of packaging materials used for dried fish marketing and distribution with insecticide may assist in control of pests (see also chapter 8). Sacks or other materials in which some insecticide is incorporated during manufacture might be used. In remote or rural areas it may be more realistic to consider the treatment of packaging material on the spot, such as by spraying with insecticide prior to use.

7.4 The Fumigation of Dried Fish

When fish is passed from processing to the packing, storage and distribution stage, infestation may be eradicated by fumigation, that is by exposing the fish to a toxic gas in a closed chamber or under a gasproof plastic sheet. This type of treatment affords no protection against reinfestation and it is therefore obviously desirable to make every effort to prevent reinfestation. Fumigation could be used for the control of infestation in dried fish, providing a vital insect controlling step between production and distribution, and disinfestation appears to warrant more emphasis than previously afforded.

Two fumigants are in general use, methyl bromide and phosphine. There are a few published references to the use of methyl bromide on dried fish. Mallamire (1957) fumigated dried fish under partial vacuum at a dosage rate of 80 g/m^3 for two hours. Galichet (1960) found six hours necessary for effective fumigation of fish in the Cameroon using methyl bromide at the same application rate but under normal atmospheric pressure. Methyl bromide, which is supplied under pressure in metal cans or cylinders, requires considerable expertise for safe and effective use. It may be ideal for well equipped commercial organizations with proper fumigation chambers, but could not be considered suitable for use in small-scale operations. The only fumigant which might be useful in these circumstances is phosphine.

All developmental stages of *D. maculatus* were controlled by a phosphine dosage of 0.1 mg/l for 72 hours (TPI, unpublished data) indicating that a CT (concentration x time) product of between 7 and 10 mg hours per liter at 27°C would suffice. This relatively low dose suggests that dried fish could easily be fumigated in 2 or 3 days at a dose of 0.2-0.5 g phosphine per 50 kg fish, although no experimental data has been published.

Phosphine is liberated from tablets, pellets or packets of aluminium or magnesium phosphide preparations which are placed in the fumigation chamber or enclosure. The gas is released when the phosphide is exposed to the air. The treatment might be in metal or rendered brick or concrete chambers or under gastight plastic sheeting or in individual plastic sacks. Phosphine usually leaves negligible chemical residues in fumigated products and repeated fumigations are possible. Methyl bromide reacts with many commodities, particularly those with a high oil content. Usually only one fumigation with methyl bromide is advisable.

The most likely situation in which fumigation of dried fish could be carried out is at a collecting centre where stocks are accumulated prior to transportation. It is unlikely that individuals in rural isolated areas will be able to undertake fumigation because of the training required for effective and safe use and because of the lack of suitable commercially available preparations marketed in small containers. Because fumigants confer no lasting protection, rapid reinfestation is possible and the product should be protected by keeping in clean stores and using clean and effective packaging barriers.

8. IMPROVED HANDLING, STORAGE AND DISTRIBUTION

8.1 Packaging

Packaging is one of the major means of reducing losses of foodstuffs during handling, storage and distribution. The basic functions of any package may be defined as:

a. Containment, enabling a specified quantity of foodstuff to be handled conveniently as a single unit.

b. Protection of the foodstuff against the various hazards of distribution.

c. Information about the product or its destination or ownership.

An effective package will, while fulfilling these functions, assist in minimizing the total unit costs of the distribution system. Although the nature of the packages differ, the same general principles apply whether the foodstuff is marketed in a bulk package from which it is dispensed by retailers, or in retail consumer packs.

Cured fish, of both European and tropical origin, is distributed almost exclusively in bulk packs of 10 kg upwards. Traditional packages as mentioned in chapter 2 have little effective function beyond containment. Wooden or cardboard boxes and some baskets may provide some protection against mechanical hazards. Any closed package provides some resistance to rain, but probably only a well-made closed wooden box, of those packages indicated, provides any control of moisture exchange with the atmosphere.

Little work appears to have been done on improving the packaging of cured fish products. Laboratory investigations, such as those of Sen *et al.* (1961) and Kandoran and Valsan (1974) have been concerned primarily with the effects of moisture-barrier wrapping materials and do not appear to have been followed up in full-scale trials under commercial conditions. In Mali, where infestation is a major problem, Guggenheim (1980) noted that baled fish was crated for distribution, but local traders found that cartons of unspecified design were more effective in reducing losses, although customs/health officials found crating highly satisfactory. Exporters from Europe have introduced some changes, in particular the use of a polyethylene film shrinkwrap around a corrugated board case for salt cod, and woven plastic fabric instead of jute for baling stock fish. No information is however available on the performance of these in practice.

It is possible that adoption of appropriate improved packaging methods could in many instances give useful reductions in losses in cured fish. However, several factors make it impossible to give recommendations for immediate adoption; trials and probably package

development work would be necessary. It is unlikely that a single package type would be most appropriate in all cured fish production and distribution systems.

8.2 Problems of Packaging Dried Fish

The first factor causing difficulty in packaging is the physical nature of cured fish. Whether processed as whole fish or as pieces, all types of cured fish are irregular in shape, leading to difficulty in assembling a neat package of economical density. The pieces of fish very often have sharp protrusions which may puncture packaging materials and also occupy space. Furthermore, the fish may be brittle and attempts to force it into a regular shaped package may cause damage. Fish which has been smoked and thereby cooked, and also fish which has suffered insect or microbial damage, is particularly liable to break-up.

The second factor creating difficulty in packaging is moisture. For safe storage without microbiological spoilage the product must have an Aw below 0.6 (see chapter 4). In an atmosphere of humidity greater than 60 percent, the dry fish will tend to pick up moisture, with consequent risk of spoilage. It would be logical therefore for waterproof-vapourproof packaging to be used to prevent this. It is not uncommon, however, for cured fish to be apparently dry on the surface but to have an appreciably higher moisture content internally due to "case-hardening" or simply to inadequate drying (see chapter 2) where a long storage life is not required. In traditional practice, except in the most humid atmospheres, further drying of the product can occur slowly during storage and marketing. If such fish were in a waterproof-vapourproof package it would be liable to spoil, because moisture diffusing from the centre would raise the humidity at the fish surface and in the air within the package to a level at which rapid mould growth could occur.

Even when the moisture content of the fish throughout its bulk is at a level suitable for long term storage (see chapter 4) there could still be some risk of spoilage in a waterproof-vapourproof package. Temperature differentials within the package could lead to migration of moisture from warmer to cooler regions, and in especially unfavourable cases to condensation of water on the walls of the package. The risk of such problems is probably greatest if fish in a transparent package is exposed to the heat of the sun. Recommendations on packaging of salted dried fish made to World Food Programme (Murray and Jobber, 1968) include the use of a paper wrap in immediate contact with the fish to absorb any condensed water, with the maximum moisture content limited to 28 percent (salt free wet basis). This is lower than for many locally prepared cured fish. However, many other hygroscopic foodstuffs are transported in waterproof-vapourproof packages without encountering such problems, and it seems probable that, as long as the package material provides some degree of thermal insulation, significant moisture migration should not occur. In small retail packages there is little chance of troublesome temperature differentials arising.

A number of other obstacles to generalized solutions to the problem of packaging of cured fish may be grouped as 'the need for the package to be appropriate to the system'. Thus, the supply of the package to the processor or merchant must be assured, the price of the package must be acceptable in relation to the price of the fish, equipment for filling or closing the package must not place undue demands on skills or services, and the package should be able to accommodate traditional trade practices of inspection and grading. In many instances, but especially with small-scale processing, these problems will outweigh purely technical difficulties in the introduction of novel packaging.

8.3 Role of Improved Packaging in Loss Reduction

Losses through infestation and some mechanical damage might be reduced, and hygiene and marketability improved, by packing individual pieces of cured fish in sealed wraps or pouches. For the majority of less industrialized countries this would represent too radical a change. The contribution to loss reduction from packaging therefore depends on the adoption of bulk packages which could bring benefits of reduced breakage, lower infestation levels and avoidance of moisture uptake leading to damage by micro-organisms.

To reduce breakage under the prevailing primitive handling and distribution conditions, it is necessary to choose a package which will be sufficiently robust to retain its integrity throughout marketing and which will distribute stresses of impact and stacking. Movement of individual pieces of fish should be prevented, and it should be possible to fill the pack by hand without causing damage to the product. Rigid packages would be preferable, perhaps with some internal padding or immediate wraps. The use of bales and sacks should certainly be avoided for the more fragile products, especially smoked fish, since breakage is possible during filling and compression as well as in transit. Baskets are of variable performance, often giving no protection against stacking loads. Containers of wood or corrugated fibreboard could give adequate mechanical protection; where these are in use already they may require simple changes in design or in quality of materials or construction to reduce damage. In particular, reduction of the size of a package to contain a maximum weight of about 15 kg would be helpful. To combine mechanical protection with moisture resistance, various types of boxes might be considered for evaluation including waxed corrugated fibreboard, polyethylene-coated solid fibreboard and polypropylene profile board.

For the package to act as a physical barrier to insects it must be well sealed, with no aperatures greater than 0.2 mm diameter, and of a material which is not readily penetrated. Boxes such as those of fibreboard and polypropylene mentioned above could be made reasonably insect-resistant by sealing all openings with adhesive tape. Wooden boxes, unless very carefully constructed, could only be sealed by use of a flexible liner. Sacks can show good insect resistance if they are a suitable multiwall paper construction, carefully manufactured and closed, but woven sacks will never be completely insect resistant. A closely-woven heavy cotton sack, with carefully sewn seams and closure, may show good results especially where (as will often be the case) a water-vapour barrier cannot be used. Bale wraps present a greater problem of sealing and it is probably not possible to do more than reduce the rate of invasion by insects.

Other materials not presently used which may be worth evaluating either as sack or baling materials in their own right, or as box-liners or components of a multiwall sack, include woven plastic fabrics (coated and uncoated), cross-laminated plastic films, microporous polypropylene film and spun-bonded polyolefines.

The use of a package resistant to insect invasion will of course only prevent damage by insects if the fish is treated to eliminate any live infestation, for example by fumigation (chapter 7) or heat treatment (chapter 5) immediately before packing. If a package which can be penetrated by fumigants were used, disinfestation could of course take place after packing. Treatment of the package material with insecticides or insect repellents could also assist in reducing infestation. Paper treated with pyrethrin formulations has been used in sacks for cereal products, and other synthetic insecticides have undergone trials (see chapter 7). However, the use of treated packaging materials would entail increased costs and difficulty in supply. Any package which is used more than once should be disinfested before being refilled, fumigation or heat treatment being the usual method.

In the absence of proven solutions to all the technical problems of packaging cured fish, any attempts to improve present practices should be made cautiously. Simple modifications to existing packages, using where possible local materials, are in many instances likely to have a significant impact on losses and to be readily accepted. Trial and demonstration of such improvements should form an early stage in a loss reduction programme. More radical changes, including the use of more sophisticated packaging materials, will usually lead to appreciable increases in packaging costs, and will often not be justifiable. Expensive packaging is most likely to be cost-effective where the value of losses is high, due to either high price of the fish or high quantitative losses during extended storage or distribution. Consumer attitudes and competition from imported processed fish could also provide justification for such changes.

8.4 Improved Handling Methods

The distribution systems indicated in chapter 2 are relatively simple, nevertheless packs of cured fish and the individual pieces of fish may be handled several times. The main hazards in handling a bulk package is dropping it, with consequent breakage of fish or failure of the package with spoilage of the contents. Improved packaging could alleviate these problems.

Handling of individual pieces exposes them to infestation and to other forms of contamination. These risks are particularly severe when the cured fish is tipped onto a woven mat, or an area of ground habitually used for sorting. Handling areas should be kept clean and insect free, and hard surfaces, or sorting tables, which could be washed, are to be advocated.

It seems likely that manual handling methods will usually continue to be appropriate to the cured fish trade. Package weights should therefore be convenient for manual handling, with an absolute maximum of 50 kg. Should palletized handling be required, however, there is unlikely to be any difficulty in selecting package dimensions which will give a satisfactory fit on a pallet.

8.5 Storage

Cured fish is likely to be stored at the processing site, at the point of marketing and distribution, and possibly at intermediate collecting centres. There are various reasons for storage, including the need to accumulate an economic load for transport, evening out seasonal variations in supply, waiting to find a buyer or for transport, and commercial strategy. The duration of storage at each point in the chain may vary substantially. While the attention given to storage should be greater where the period is long, it must be recognized that severe damage could result from even a short period of bad storage.

Under the very primitive conditions found in small-scale processing operations, fish will inevitably become infested. Reprocessing (such as resmoking, use of solar driers; see chapter 6) may be useful in disinfesting and redrying fish, and hence reducing losses where storage facilities are very crude.

As an absolute minimum, a storage facility should provide:

a. Security, appropriate to the location.

b. A roof, to shade the stored fish, to keep off rain, and to reduce any possible overnight formation of dew on the fish.

c. Protection from groundwater, either by raising the commodity above the ground or by providing a floor incorporating a water vapour barrier.

A good store should include numerous other features to aid loss reduction, either directly or indirectly, by assisting good management. These include:

a. Rodent proofing.

b. Bird proofing.

c. Controllable ventilation.

d. Walls and floor free from crevices which will harbour insect pests, and suitable for treatment with insecticides.

e. Sufficiently large to permit orderly stacking with access all around the stacks (enabling fumigation or other treatments) and to enable first in/first out stock management.

f. Insect proofing, where not too expensive.

A cured fish store should preferably be reserved for this commodity only, the strong odour making the storage of other foodstuffs nearby undesirable, and the storage of non-foods with foodstuffs is not a good practice.

In estimating the capacity of a store, the stowage factor of the packed fish must be taken into account. This may present some difficulty as the density can vary considerably according to the type of fish and method of presentation. Baled stockfish from Europe, which is packed using a mechanical press, typically occupies 2.3 m^3/t. No reliable figures for cured fish produced under tropical conditions are available, but it seems likely that small fillets, carefully assembled into the pack by hand, could give a somewhat higher density whereas the stowage factor could rise to as much as 5 m^3/t for those cured fish which are traditionally presented in coils.

The proportion of a store that can be filled, while following recommended store management practices, falls as the number of lots to be segregated is increased and as the floor area is reduced. Thus in a medium sized store (of plan dimensions 20 m x 10 m) the proportion of the floor that can be utilized is 72 percent if a single stack can be built, falling to 60 percent for four equal stacks. The corresponding weights of fish, assuming 3-m high stacks and 3 m^3/t, would be 144 and 120 t. In a small store (10 m x 5 m) making the same assumptions the utilization factors are about 48 and 30 percent, and the weights stored perhaps 24 and 15 t.

8.6 Store Management

The general principles of store management should be as for any durable foodstuff. In a well-run store the commodity is neatly and safely stacked with adequate clearance from walls and structural members. Responsibility for the following aspects should be clearly allocated, either to the storekeeper or another person.

a. Accounting for stocks: each lot clearly identified, older stocks normally distributed first.

b. Cleanliness of store: a regular schedule for sweeping floor and walls, with proper means for disposal of sweepings and spillage.

c. Building integrity: regular inspections and arrangements made for necessary repair and maintenance.

d. Inspection of foodstuff on receipt into store.

e. Regular inspection of foodstuff during storage (if stored for 1 month or more).

f. Reconditioning such as redrying (or resmoking) and repacking of substandard commodity.

g. Pest control: perform or arrange insecticide treatment of building fabric, rodent baiting, disinfesting or spraying of produce stacks, as necessary.

h. Safety of workers in the store.

The storekeeper should be given appropriate training to enable him to carry out these tasks effectively, and should be provided with the necessary equipment and budget.

8.7 Distribution

Transport in the initial stages of distribution from the point of production, and perhaps in the final market, might be by head-load or on a pack animal. These methods may impose constraints on the type and size of package used, but will not lead to any special risk to the cured fish.

Land transport in carts, lorries or railway wagons exposes the commodity to contamination by dust and to possible wetting by rain. Except for very short journeys, therefore, the load should always be covered with a tarpaulin unless a closed van is used. Vehicles, especially if used repeatedly for carrying cured fish, can provide a source of infestation. Before loading, therefore, all vehicles should be carefully swept out to remove all food residues. Treatment of the load platform with a suitable insecticide should be undertaken at intervals. Transporting cured fish from areas of low humidity to ones with high humidity will expose the products to moisture absorption, so packaging material should be selected with care.

Transport by ship or boat presents the same risk of cross-infestation and remedial measures may be more difficult. There is also a greater risk of water-damage, by spray and bilge-water in the case of small boats and with the added hazard of condensation (sweating) for larger vessels. Cured fish exported from northern countries in winter is particularly at risk at the time of unloading in a humid tropical climate, if the commodity temperature has not had time to rise. For all journeys on water a package providing some resistance to wetting is therefore preferable.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Losses in cured fish are high, but there are no easy solutions to the problems. The complexity and diversity of these problems should be apparent, while the economic resources available to solve them are extremely limited. There is only an extremely limited amount of data on the levels of losses, and many of the figures which do exist are generalities which are of little assistance in identifying appropriate remedial measures. There must be incentives for loss reduction if there are to be significant improvements in the present situation. As an overall policy the demonstration of economic losses and the introduction of quality control (guidelines in Appendix 1) must be used as the means of providing such incentives. Well directed, trained and organized extension services will clearly be absolutely essential to any loss reducing strategy. A method is needed whereby losses can be assessed and causes identified so that an effective loss-reducing technique can be introduced to the particular situation. Table 13 summarizes the many technical options available, but many of these methods need to be developed and their effectiveness assessed before they can be firmly recommended.

9.2 Four-Stage Strategy for Loss Reduction

a. Initiate work to measure the type, cause and extent of losses, and identify, develop and evaluate countermeasures.

b. Use information obtained from a. to determine which are the most appropriate techniques for the specific circumstances.

c. Draw up a guide of the established techniques suitable for use, including guidelines on good housekeeping and quality control.

d. Formulate and implement extension programmes to introduce the improved techniques to commercial situations.

Table 13

Summary of loss-reducing countermeasures: possible and suggested techniques to counter specific causes of losses

Cause of loss	Countermeasures
a. Spoilage during wet weather	Use of weatherproof smoking kilns. Heavy salting and holding in a covered area to preserve fish until sun drying is possible. Supplementary drying.
b. Halophilic bacteria and moulds	Improved salt quality and salting technique. Adequate drying. Microbial inhibitors. Moisture-proof packaging.
c. Blow-fly infestation	Use of salt and improved salting technique. Adequate drying of products. Improved drying, e.g., raised racks, solar driers. Use of insecticides. Use of fly screens.
d. Beetle infestation	Use of salt and improved salting technique. Very thorough drying. Use of raised drying racks. Disinfestation by fumigation, or elevated temperature treatment (resmoking, solar drying), or irradiation. Improved packaging. Improved storage facilities. Use of insecticides. Reduction of storage time.
e. Fragmentation	Improved smoking technique. Possible use of salt. Better packaging and handling practices. Prevention of insect infestation and microbial attack.
f. Birds, rodents and domestic animals	Use of nets, fences, raised drying racks. Better storage facilities.

9.3 Areas for Further Research and Development Work

BEFORE LOSS MEASUREMENT AND COUNTERMEASURE EVALUATION CAN START, A METHODOLOGY IS NEEDED AS A MATTER OF URGENCY FOR ASSESSING LOSSES APPLICABLE TO ALL STAGES OF PROCESSING, STORAGE AND DISTRIBUTION. Proposals are made in Appendix 2, but this must be field tested as the initial stage of the recommended work programme.

When a suitable method of loss assessment has been developed the following priority areas, that is, projects to be started as soon as possible, have been identified:

a. Little is known about the relationships between processing conditions, fragmentation (and nutritional value losses) in hot-smoked fish (discussed in Sections 3.1.1; 3.3.5 and 6.2.5); it is recommended that they are investigated. THIS IS A HIGH PRIORITY RESEARCH AREA.

b. Cured fish composition (such as moisture, salt and fat contents) and lengths of storage are fundamental factors in determining levels of losses caused by insect infestation (chapter 5) and microbial action (chapter 4), but have not been studied in detail. It is recommended that all of these relationships are investigated.

c. Reducing storage times (see chapters 4 and 5) and improving distribution (see chapter 8) will reduce losses, therefore it is recommended that the structures of cured fish industries be studied in order to identify possible changes.

d. Evaluation of the biological effectiveness of candidate insecticides (see chapter 7), followed by a detailed study of safe residue levels in treated fish with respect to insecticides used, method of application and the eating habits of the consumer is recommended as insecticides may have an important role to play in countering insect infestation. THIS IS A HIGH PRIORITY RESEARCH AREA.

e. Salting is known to reduce losses due to insect infestation (see chapter 3 and section 5.4.4), therefore it is recommended that the feasibility and benefits of using salt where it is not presently used, and improving the quality of that which is used, be evaluated (discussed in sections 6.2.1 and 6.2.2). THIS IS A HIGH PRIORITY RESEARCH AREA.

f. Disinfestation and the use of insect-proof areas or containers will reduce losses during storage and distribution (see chapters 6 and 8). It is recommended that insect disinfestation techniques, especially fumigation (section 7.4) and high temperatures (sections 5.4.1; 6.2.4; 6.2.5), and improved storage facilities and packaging (chapter 8) for disinfested dried fish be developed and evaluated. THIS IS A HIGH PRIORITY RESEARCH AREA.

g. Improved drying techniques, solar driers and smoking kilns for example, and physical barriers such as insect screens may be effective in countering blow-flies (see chapter 6); it is recommended that these methods are further developed. THIS IS A HIGH PRIORITY RESEARCH AREA.

h. Microbial inhibitors (see chapter 4) and the use of moisture-resistant packaging (see chapter 8) can extend the storage life of cured fish; it is recommended that they are investigated.

Areas for longer term research (to be investigated after priority areas):

a. Investigation and evaluation of potentially harmful compounds in cured fish, such as the compounds associated with traditionally smoked fish, the products of lipid oxidation (section 3.1.2) and mycotoxins (section 4.4) are recommended as they may be causing health and nutritional problems.

b. Further evaluation of the feasibility of artificial drying and the development of more advanced artificial driers is recommended (see section 6.2.4) as they may prove to be appropriate under some circumstances.

c. Investigation of the possible uses of gamma irradiation in the cured fish industry is recommended as future technical developments may make this an attractive option as a disinfestation (section 5.5) and sterilization (section 4.6) technique.

APPENDIX 1

QUALITY CONTROL STANDARDS FOR CURED FISH

1. Introduction

While standards will depend on product and location, some standards for specific products in a particular location have been recommended.

Proposals by Watanabe and Dzekedzeke (1970) are reproduced below as a guide to how such standards can be prepared. Standards for dried sardine have been prepared on very similar lines by Watanabe and Choongo (1971).

The standard is designed primarily to meet the present requirements of local consumers and is based on organoleptic observations and chemical analyses of 83 samples obtained from retailers at the Luburma Market in Lusaka during the period August 1968 to January 1969.

As the resources for the establishment of proper inspection services are limited, the standards are designed in a simple form so that the inspectors can be easily trained in a short time. Product inspection would start at the wholesale markets located on the rail lines and be followed later by inspection at the producer and retailer levels.

2. Product Description and Grades

Product description: Split, dried, smoked bream shall consist of fish of the *Tilapia* spp. prepared in the following styles:

Style A, non-salted: Non-salted, split, dried, smoked bream shall be prepared from fresh whole bream which, after scaling, splitting open along the backbone without removing head, backbone and skin, are eviscerated and washed, dried and cured by smoke. After completion of the smoke curing, the bream may again be dried to the desired water content.

Weight classification for Style A:

Small - 1/4 lb (114 g) and under

Medium - 1/4 lb (114 g) up to 1/2 lb (227 g)

Large - 1/2 lb (227 g) and over

Style B, salted: Salted, split, dried, smoked bream shall be prepared from fresh whole bream which, after scaling, splitting open along the backbone without removing head, backbone and skin, are eviscerated and washed, cured by immersing in a saturated salt solution (24° Baumé), dried and cured by smoke.

Weight classification for Style B:

Small - 1/3 lb (159 g) and under

Medium - 1/3 lb (150 g) up to 2/3 lb (300 g)

Large - 2/3 lb (300 g) and over

Grades of split, dried, smoked bream: In each style three grades are prepared as follows:

"Zambia Grade A" is split, dried, smoked bream with normal colour, odour and texture, that is clean and free from insect infestation and mould contamination. Water and salt content, pH values and defect tolerances shall be as specified in Table 14.

"Zambia Grade B" is split, dried, smoked bream that may show significant defects within the tolerances specified in Table 14. Water and salt content and pH values shall be within the limits specified in Table 14.

"Zambia Grade C" is split, dried, smoked bream that show significant defects which exceed the tolerances for "Zambia Grade B".

3. Determination of the Grade

The grade is determined by examining the product in accordance with the schedule of defect tolerances as shown in Table 14. The quality factors and definitions used in Table 14 are described below.

"Discolouration" of the cut surface refers to the presence of colours other than the characteristic yellowish brown. Only discolorations which are clearly visible are considered as defects.

Discolorations more frequently encountered are described in Table 15.

"Brittleness" refers to a defect of texture that causes breakage under normal handling. Usually this results from smoking fish at excessively high temperatures, particularly fish that were not properly dried before smoking. The Style B Salted product is less susceptible to this defect than Style A Non-salted products. The degree of brittleness is measured by noting the cracks on the cut surface.

"Insect infestation" is caused by flies and by beetles (see chapter 5). The gills are usually affected first, then the flesh immediately below the skin.

"Mould contamination" (see chapter 4) which usually grows on the cut surface of the products. Mould damage indicates that the product was not properly dried during processing, and mould contamination is measured by noting the area of the surface covered by mould colonies.

"Odour defects" refer to off odours resulting from improper or excessive smoking, and odours associated with rancidity and spoilage.

"Water and salt content" are determined according to the Official Methods of Analysis of the Association of Official Analytical Chemists (see also Appendix 3).

Definitions:

"Normal" refers to a condition that conforms to the usual, regular or accepted characteristics of the properly processed product.

"Slight" refers to a condition that is scarcely noticeable but that does affect the appearance and/or eating quality of the product.

"Moderate" refers to a condition that is fairly noticeable but that is not seriously objectionable.

"Significant" refers to a condition that is readily noticeable and that considerably affects the appearance and/or eating quality of the product.

"Excessive" refers to a condition that is readily noticeable and that seriously affects the appearance and/or eating quality of the product.

Table 14

Recommended quality grades with defect tolerances for grading of split, dried, smoked bream

Factors of quality	Grade A		Grade B	Grade C
	Normal (no defects	Tolerance[a] (3 or less minor defects as listed below)	Tolerance[b] (4 or less major defects as listed below)	
Discoloration of cut surfaces (white, yellow, brown, green)	normal (yellowish brown)	slight	significant	excessive
Brittleness	none	moderate	moderate	significant
Cleaning defects (residuals of blood and viscera, other objects foreign to the products)	normal (slight residuals)	moderate	significant	excessive
Insect infestation	none	none	slight	significant
Mould contamination	none	none	slight	significant
Odour defects (rancid, ammoniacal, smoky)	normal (moderately rancid)	slightly ammoniacal, smoky	significantly rancid, ammoniacal, smoky	excessively rancid, ammoniacal, smoky
Water and salt contents — Form A (non-salted)	water maximum 35% salt under 1%	-	water 35 to 50% salt under 1%	water over 50% salt under 1%
Water and salt contents — Form B (salted)	water maximum 45%, salt 8 to 15%	-	water 45 to 55% salt 5 to 8% or 15 to 20%	water over 55% salt under 5% or over 20%
pH	6.0 to 6.9	-	6.9 to 7.2	over 7.2 or under 6.0

a/ Four or more defects as listed under Grade A reduce product to Grade B

b/ Five or more defects as listed under Grade B reduce product to Grade C

Table 15

Type of discoloration with causes and description

Type of discoloration	Description	Cause
White	Grey to white spots usually occurring on the surface of thinner parts of the fish	Over-salting or poor washing after salting for Style B product
	Mould colonies	Microbiological
Yellow	Pale yellow to yellow	Under-smoking
	Mould colonies	Microbiological
Brown	Dark brown to black	Over-smoking
	Dark brown, usually occurring on the surface of the belly cavity, indicating that the product was prepared from stale fish. It is associated with a mushy texture	Enzymatic digestion
	Dark brown with glossy surface, mainly occurring on fatty fish, and associated with a rancid odour	Rancidity
	Black blood stains, remains of kidney around the backbone, black membrane on belly cavity	Poor cleaning and washing
Green	Mould colonies	Microbiological

APPENDIX 2

APPROACHES TO THE ASSESSMENT OF LOSSES IN CURED FISH

1. Introduction

The factors to be considered in assessing losses are discussed and a tentative methodology is outlined. It must be stressed tht the methodology offered has been derived from only limited work on fish losses together with experience gained from assessing losses in other products. The approach requires field testing and further development in the light of practical experience.

Loss assessment should form an initial phase of the programme concerned with achieving improvements and a reduction of losses. It can be used to enable the specific problems of existing methods to be identified, measured and evaluated in an objective way. Loss assessment may also be employed in extension programmes as a means of demonstrating the worth of improvements.

2. Procedure for Assessing Losses

The first prerequisite is to define the objective for the study, which may include one or all of the following aspects:

a. To determine the amount of wet fish which is lost at the curing stage and fails to become processed into a satisfactory cured product.

b. To determine the amount of cured fish which is produced but lost before reaching the marketing system.

c. To determine the physical deterioration in cured fish between the curing stages and purchase by the consumer and to assess the financial consequences.

d. To consider consumer preferences for fish and to evaluate nutritional values of available cured fish.

As a first practical step it is necessary to obtain full and appropriate background information about the system in which the cured fish is moving. This will be in relation to the:

a. Geographical locations concerned with the industry and their environmental and climatic features.

b. Handling and transport systems.

c. Ownership changes and variations in unit value of products.

d. Time scale involved and seasonal nature of operations.

e. Estimates of total amounts handled.

f. The parameters set for acceptability (or quality and grade if such exist).

Much of this information will be obtained through observation and discussion with those close to the trade, and by consulting reports and records. Completion of the data required may, however, necessitate planning and executing a survey of the field situation.

There are three basic elements pertinent to the consideration of losses of cured fish:

a. Determination of the type of losses.

b. Measurement of the amount and extent of loss.

c. Evaluation of the importance of the loss.

The causes of losses should be readily apparent, but quantitative evaluation presents some problems which are discussed later.

3. Survey and Sampling Methods

The practicalities of organising a survey will depend so much upon local conditions and objectives that guidelines can be laid down only in a general way. The scale of survey embarked upon will depend very much upon what is already known and how much additional detail is sought. Since it is not practical to examine the whole industry, care must be exercised in the selection of those factors which are to be studied. The survey may be of one sector, one route, one type of cured fish entering one market. Whatever the approach care must be taken to define the component elements or stages of the fish curing trade, and to decide how much measurement can be reasonably undertaken. It should be borne in mind that careful stratification of the stages should be done for the survey so as to accommodate the distinct variations which may be found between different regions and trades.

This inevitably leads to multiplication of the amount of work to be carried out. For example, if there are two species of fish (large and small) cured in two ways (salted and smoked) transported in two ways (road and rail) to two markets (near and far), this may indicate the need for a minimum of 16 sets of data. Sampling of fish of variable size and weight presents problems. Consequently it may be best to use a comparison with a similar fish as the basis of measurement, and it is easier to work with fleshy rather than bony species. Individual fish or whole bales may be tagged with a label as a means of identification and followed through the system. Although difficult to quantify, an attempt should be made to objectively measure loss, and some parameters for measurement are discussed below.

4. Indirect Measurements of Losses

Measurements of pest density, and even the physical separation and weighing of frass resulting from insect infestation have been suggested as being suitable approaches to the measurement of *Dermestes* spp. activity in dried fish (Moes, 1980). Both will relate in some way to loss levels, but neither can be regarded as reliable measurements of losses.

Pest density has been found to be subject to wide fluctuation even within the same sample of fish (Moes, 1980) and as both the adults and larvae are able to freely migrate this is perhaps not surprising. The relationship between pest density and loss of nutritionally valuable parts of the fish will be a complex one, even if truly representative values of pest density could be obtained. Larvae will feed and develop causing considerable losses without leading to an immediate increase in pest density (refer to chapter 5 for details of life-cycles). The very marked migrations of *Dermestes* spp. due to daily temperature fluctuations have also been noted earlier, so unless extreme care is taken pest densities will depend to a very large extent on the time of day and on what part of the heap or sack of fish the sample was taken from.

5. Direct Measurements of Losses

Losses should be viewed as a loss of weight of nutrient (which is potentially available to the consumer) and as a loss of income (to a trader whose products decrease in quantity and/or quality). Measuring these losses as directly as possible has very clear advantages in that margins of error will be minimized and that direct simple measurements are far more likely to be of use in extension work than any sophisticated indirect method. Direct

weight measurement can be performed quickly, easily and non-destructively with a simple spring balance or scales, and so a change in weight is the recommended parameter whereby losses can be quantified.

If cured fish was a uniform product of fixed composition, then weight losses could be directly related to losses of nutrients. This is, however, not the case as cured fish consists of several components which can be put into four categories:

a. Edible flesh and nutrients, mainly protein but including fat.

b. Moisture content.

c. Non-edible bony material.

d. Salt (if added).

During processing and storage these components exhibit different characteristics and overall weight changes are a sum of all the changes in the different components. The real area of interest is component (a) which cannot be measured directly, but can be calculated by correcting for the effect of the other components.

6. Effect of Moisture Content

Changes in moisture content must be corrected for by expressing losses on a dry weight basis, otherwise weight losses will not relate directly to actual losses of nutrients. A method for moisture determination is given in Appendix 3, and the application of the correction factor is as follows:

At the start (time = t_1) weight of fish = W_1 and moisture content (percent by weight of the fish = M_1

At the end (time = t_2), weight of fish = W_2 and moisture content = M_2

Thus the weight of fish solids at t_1 (f_1) = $\frac{W_1 (100 - M_1)}{100}$

[equation 1]

and a similar equation can be derived for the weight of fish solids (f_2) at t_2

Thus the effective loss in fish (f_1-f_2) = $\frac{W_1 (100 - M_1)}{100} - \frac{W_2 (100 - M_2)}{100}$

[equation 2]

This is an especially important consideration when assessing losses during processing where moisture contents are reduced considerably, making simple weight measurements taken without moisture determinations meaningless. The same will be true to a lesser extent if the atmospheric relative humidities at t_1 and t_2 are widely different, such as can occur during a wet season or the export of products from dry to humid areas.

As an illustration, say 100 kg of dried fish is found to weigh 90 kg after a month's storage, but over this period the moisture content has risen from 15 to 20 percent.

The effective loss in fish (using equation 2)

$$f_1 - f_2 = \frac{100\ (100 - 15)}{100} - \frac{90\ (100 - 20)}{100}$$

$$= 85 - 72$$

$$= 13 \text{ percent, not } 10 \text{ percent (100 to 90 kg)}$$

7. Effect of Bone Content

Another complication is that insects consume fish protein leaving inedible parts such as bone, and also render portions inedible. By weighing a representative sample, physically removing the edible parts and re-weighing these, an estimate of the proportion of edible material can be made. By assuming that moisture-corrected weight losses are due entirely to the loss of edible material (an assumption which is probably correct to a first approximation) it is possible to correct for this factor. Previously edible parts rendered inedible, but which remain as part of the product, would not appear as a loss unless physically removed before W_2 is measured. By assuming the composition of the bone is constant then it is logical to analyse the composition of the edible parts of the fish separated from the inedible part. In theory the non-edible bone is then effectively removed from the analysis of the results. Unfortunately in practice it may not be possible to achieve this goal as it may prove impossible to separate all the bone from the flesh. For this reason, using fillets or deboned fish would reduce errors and make the interpretation of results easier.

Deriving an equation as follows: At the start (t_1) total weight of fish solids (dry weight basis) = f_1; weight of edible fish solids = e_1; and at the end t_2, f_2 and e_2 are similarly defined.

The proportion of edible solids initially (k_1) $= \frac{e_1}{f_1}$

/equation 3/

By assuming only edible parts are lost $f_1 - f_2 = e_1 - e_2$

The wanted value is the proportion of edible material lost (L) $= \frac{(f_1 - f_2) \times 100\%}{k_1\ f_1}$

/equation 4/

Consider the following example using dried unsalted fish weighed before and after storage. The moisture content was found to be constant, but 100 kg of dried fish was found to weigh 90 kg at the end of the experiment. The head and backbone had been left in the product and a 1 kg representative sample of the original product was found to consist of 800 g of flesh and 200 g of bone.

Using equation 3, $k_1 = \frac{800}{1000} = 0.8$

Substituting into equation 4
Loss of edible material, $(L) = \frac{(100 - 90)}{0.8 \cdot 100} \times 100\%$

$$= \frac{10\%}{0.8} = 12.5\%$$

8. Salt Content

As salt content affects infestability (and therefore losses due to insects) and the Aw (and hence the storage characteristics) the amount present should be determined. A method for this is given in Appendix 3. Quantities of fish can be expressed on a salt-free basis to correct for possible losses of salt itself.

9. Financial Losses

Losses in quantity and quality have financial consequences for all sections of the cured fish trade who are personally involved (e.g., fishermen, processors, distributors, retailers, consumers), and the prospect of an increased income resulting from loss reduction will be a useful tool in putting improvements into commercial practice. Some simple financial evaluation based on local prices of fish and fish products will be worthwhile in this context, even though such evaluations may over-simplify the real financial impact of any reduction in losses.

Moes (1980) examined the mark-up of the products during distribution. As traders obviously run their businesses at a profit, the mark-up must set a maximum level for losses sustained at that particular stage in distribution, although a large mark-up does not necessarily mean that losses are substantial. This may provide a useful check when the losses experienced under commercial conditions are assessed.

10. Quality Losses

Low quality as perceived by a consumer may be shown by a correspondingly low price, although due to the workings of a market, price will be a relative rather than absolute evaluation. If both good and bad products are available in sufficient quantities it may mean that only the good ones will sell; the inferior ones will not necessarily become less expensive.

Objective quality measurement is difficult as quality perceived by the consumer is such a complex judgement. Chemical analysis is not necessarily useful as a realistic indicator of quality. Assessments of quality must be done in the market-place by an experienced assessor familiar with local preferences. The opinions of those affected or responsible for quality should be sought - namely processor, transporter, merchant and consumer. The factors of importance are:

a. Appearance
b. Colour } and hence whether over or under dried
c. Smell

d. Evidence of mouldiness and decay

e. Consistency and texture of flesh

f. Proportion of bone and skin to muscle tissue

g. Size of pieces and their relative frequency

h. Presence of insect infestation

Some suggested standards are given in Appendix 1.

11. Constraints to Loss Assessment

The major constraints which may impose restrictions on the scope of the loss investigation may include:

a. Limitation of the study to a particular season, geographical area, trade route or market sector;

b. limitation due to the size of budget committed, number and qualification of available staff, adequacy of project transport and analytical facilities, time constraints;

c. the degree of cooperation forthcoming and the access that can be obtained to information about the operations of the commercial sector.

Adequate transport and some minimal laboratory facilities are certainly essential if any worthwhile survey is to be attempted.

12. Evaluation of Losses

Once the quantitative figures for loss are obtained they may be presented in that form or considered in financial terms. This can be done by reference to market standards and consumer judgements related to value. It should be recognized that broken fish, fish pieces and even dust may often have separate uses and therefore some value.

Throughout the study the aim should be to record and process data in a manner which will enable comparison with future work and an evaluation of improved methods of preservation and handling to be carried out.

APPENDIX 3

CHEMICAL ANALYSIS

1. Useful Assays

For full details of methods of analysing foods there are several standard works such as Pearson (1970; several editions available) and the publications of the Association of Official Analytical Chemists (AOAC).

Moisture and salt contents are the most important analyses to use for general loss assessment. A simple method for each is described below.

Other assays which may be of use are:

Ash and acid-insoluble ash for measuring bone and grit contents;
Fat and protein content;
Total Volatile Bases (TVB) as an index of microbial spoilage;
Thiobarbituric Acid Assay (TBA) as an index of rancidity.

2. Moisture Content

Whilst more accurate methods exist, the following simple method gives sufficiently accurate results using the simplest equipment.

Labelled moisture dishes, with a layer of acid-washed sand in the bottom, are left to dry overnight in an oven at 105°C. Remove from oven and place in a desiccator for 30 min to cool. Weigh accurately on an analytical balance (W_1).

Place 2-5 g of a representative sample of flesh into the dish and re-weigh accurately (W_2). All samples should be in duplicate or triplicate. Return the dishes to the oven and leave overnight. Remove the dishes from the oven and again desiccate for 30 min to cool before accurately reweighing (W_3).

Percentage of moisture is calculated as follows:

$$\% \text{ moisture} = \frac{(W_2 - W_3) \times 100}{(W_2 - W_1)}$$

For dried fish where fat determinations are not to be performed the acid-washed sand may be omitted. If the dried sample is to be retained for subsequent fat determinations the use of acid-washed sand is strongly advisable.

3. Salt Content

The following titration is suitable for products with the high salt contents found in some cured fish products.

Reagents: 0.1 N $AgNO_3$

Potassium chromate indicator solution
(1 percent w/v solution in water)

Method:

Approximately 2 g of a representative sample is accurately weighed and macerated in distilled water for about 2 min. The extract is transferred quantitatively into a 250 ml volumetric flask and made up to volume. 25 ml aliquots of this are titrated against 0.1 N $AgNO_3$ using the potassium chromate indicator (end point yellow to red). The results are calculated as follows:

$$\% \text{ NaCl} = \frac{\text{titration volume} \times 5.8}{\text{sample weight}}$$

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